Vol. 19.—No. 113. MARCH, 1939. Price 2/-. [Subscription 24/- per annum post free.]

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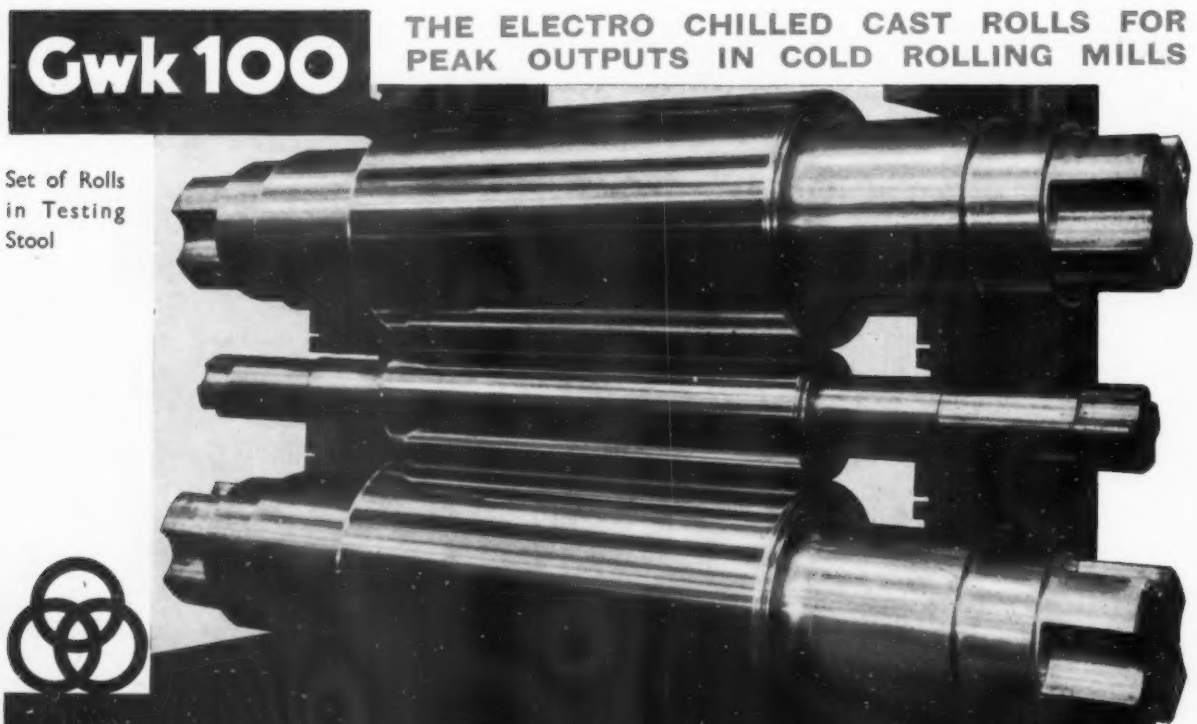
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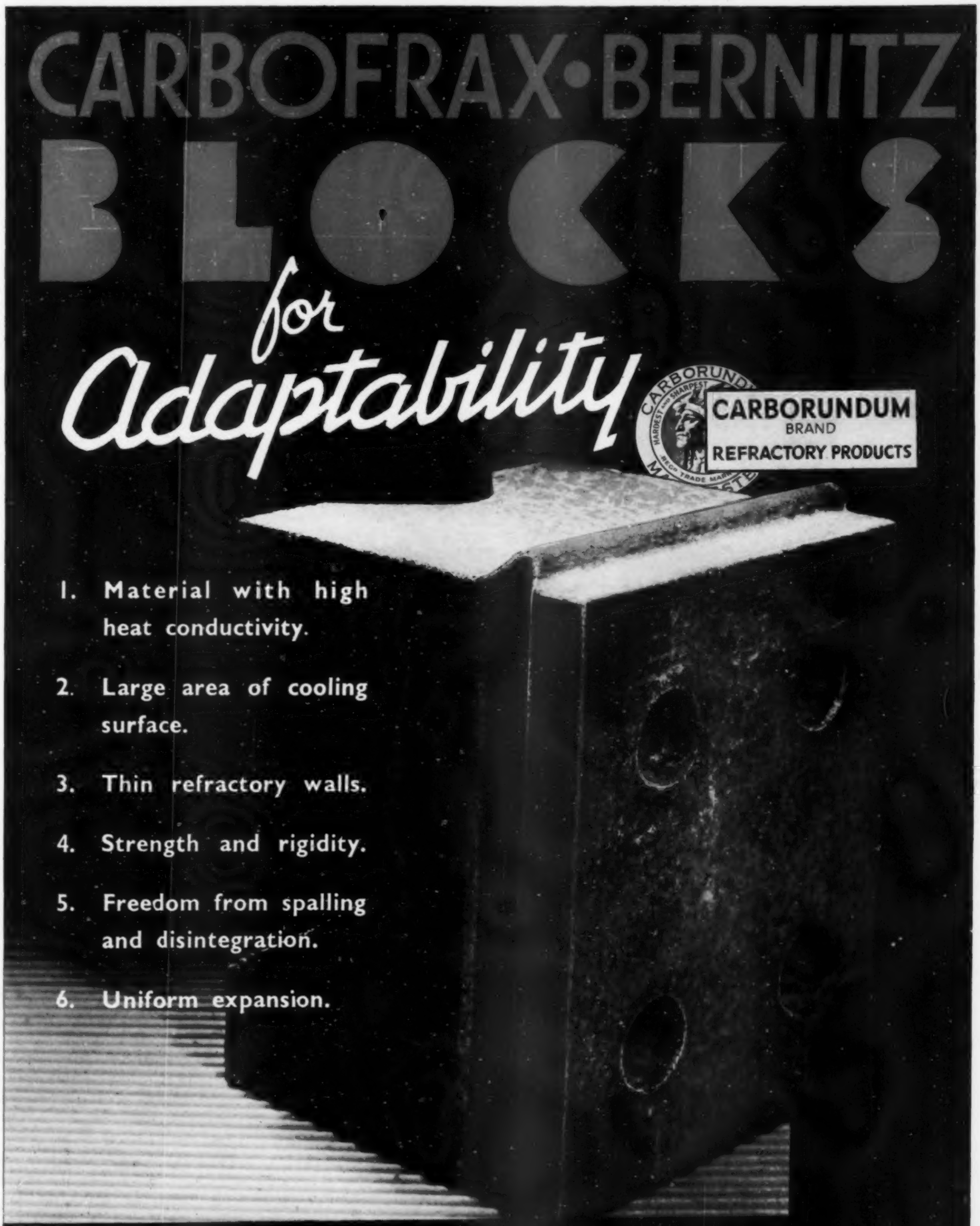
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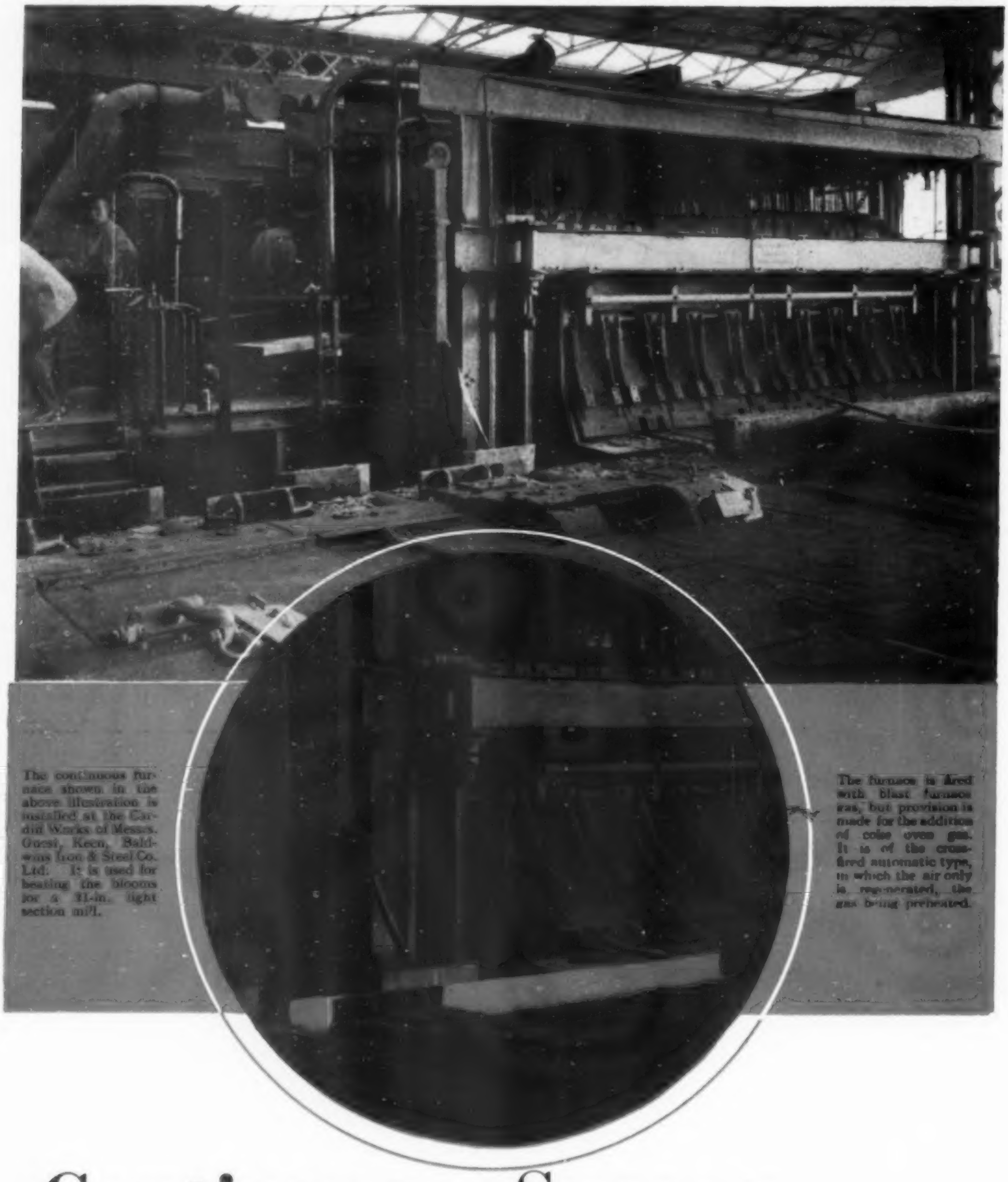

The continuous furnace shown in the above illustration is installed at the Cardiff Works of Messrs. Guest, Keen, Baldwins Iron & Steel Co. Ltd. It is used for heating the blooms for a 11-in. light section mill.

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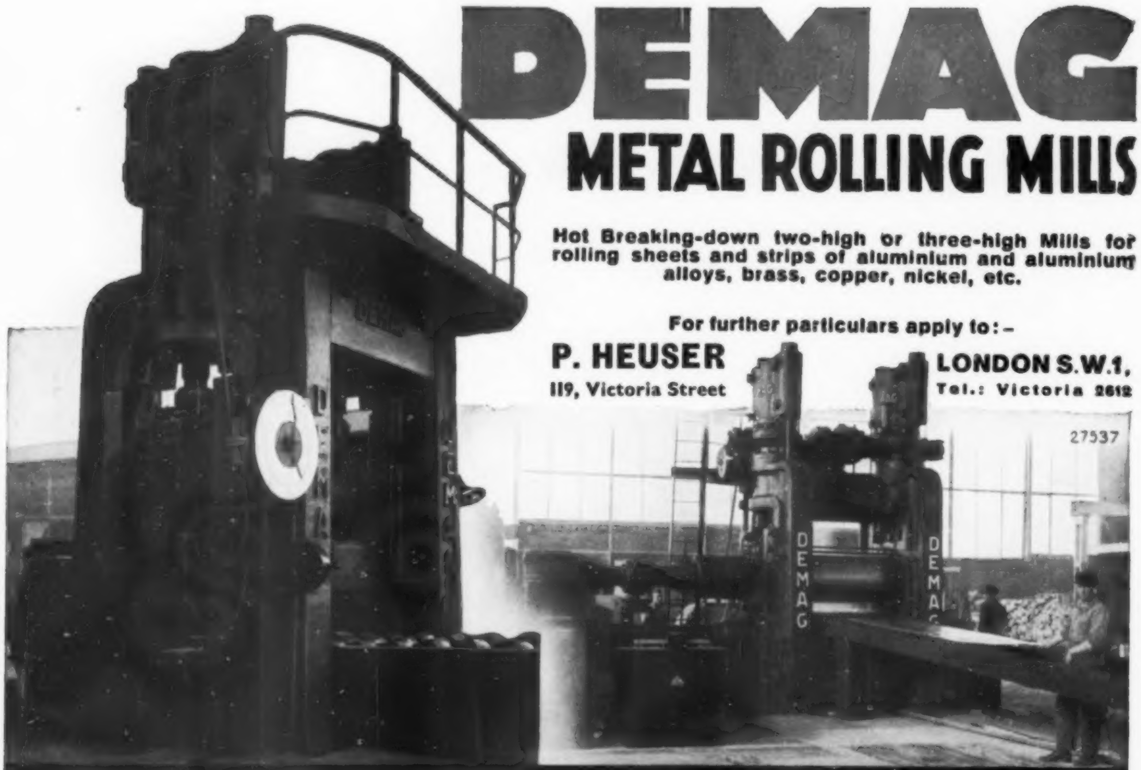
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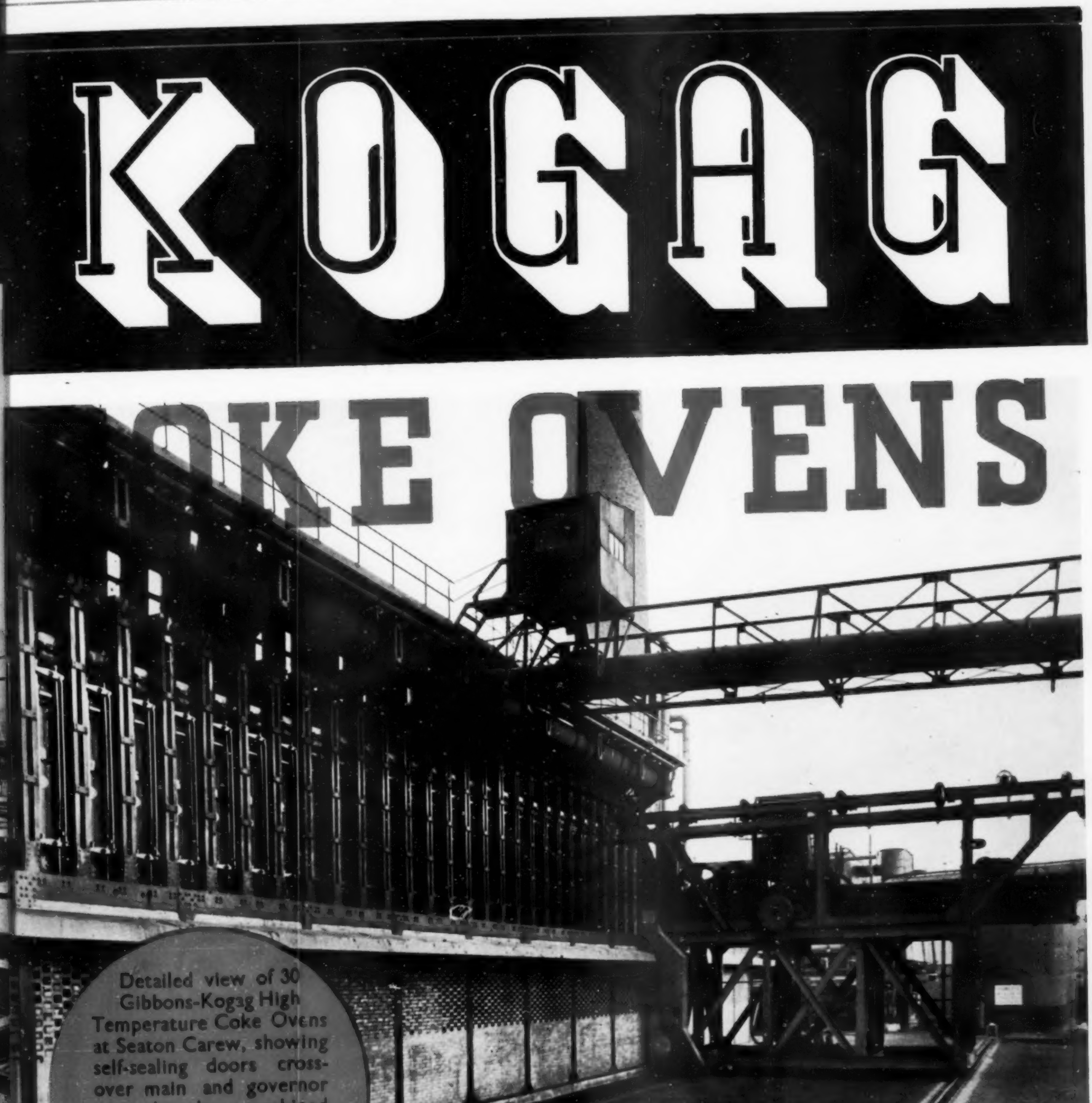
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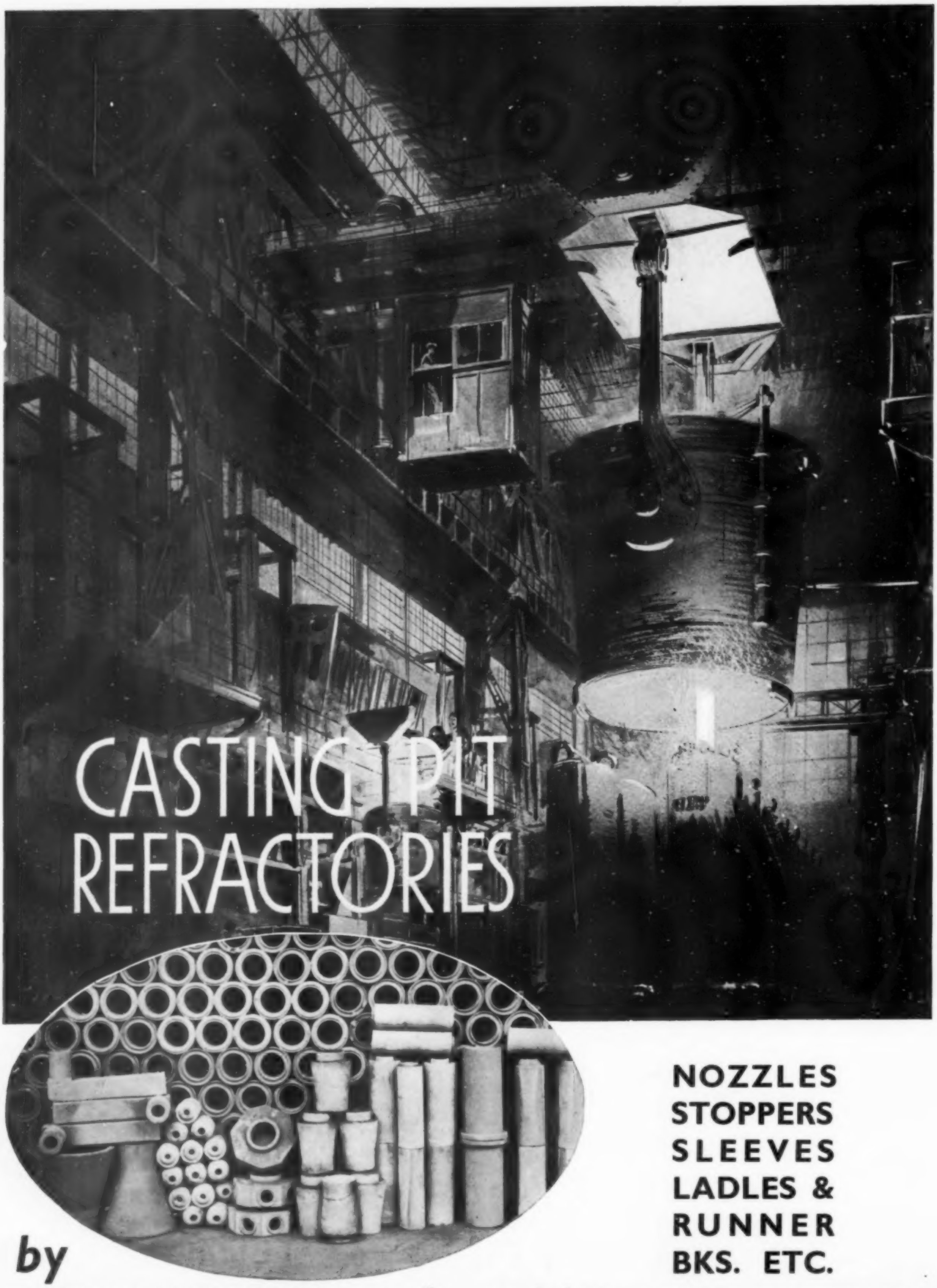
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The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

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PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone:* *Central* 0098.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

MARCH, 1939. VOL. XIX, No. 113.

Manufacture of Composite Metals by Carbon Arc Welding

By Robert E. Kinkead*

The need and utility of composite or clad metals and a method of making them is discussed. A method is described by which a stainless steel coating is formed on an ingot surface by automatic carbon arc welding. Experimental equipment is briefly referred to and results given. Attention is directed to the nature of the bond produced. Typical analysis data on surface alloyed slabs are tabulated, and costs of arc-welded clad material are discussed.

THE use of composite materials is reflected in many and varied forms. Galvanised wire, pipe and sheets combine the strength and low cost of steel with the corrosion resistance of zinc. Steel is coated with glass, rubber, copper, brass, paint, lacquer, alloys for hard facing, etc.—all for the purpose of increasing utility and serviceability.

The actuating motive in the use of composite metals is usually one of reducing the initial cost or the cost of application. Thus, copper-clad steel wire for railway signal bonds lasts ten to twenty times as long as pure copper bonds of the same initial cost, on account of the resistance of the steel core to destruction by vibration. Nickel-clad steel, used for making vessels which handle food products, costs about one-half that of solid nickel-plate for the same purpose. The composite has greater strength, and, since only one side can possibly come in contact with food, serves the purpose as well as solid nickel-plate. No one will knowingly pay £250 for solid nickel-plate when £125 spent for nickel-clad steel will satisfy requirements equally as well.

Fig. 1.—Experimental equipment used for making composite metals by carbon arc welding.

The chromium nickel alloys which have been developed in recent years have found many uses. The 18% chromium with 8% nickel specification, with additions of possibly molybdenum, columbium, or titanium, comprise the most popular group of stainless steels at the present time. The use of these almost noble metals is inhibited by the high price for which they must be sold. At $580 per ton base price 18–8 costs roughly 14 times as much as carbon steel. For about half the known uses, low carbon steel with a properly applied cladding of 18–8 would serve the purpose just as well as solid stainless. The price might be about half for the composite material as that for the solid stainless. With a 1937 production of 75,851 tons of finished stainless and heat-resisting alloys, having an aggregate value of about $60,000,000, the desirability of composite material is obvious.

While the advantages of composites of low carbon steel and very expensive metals is striking, the economies of composite metals are by no means restricted by such cases. Thus, one of the serious problems which has been encountered in the design and construction of welded steel machinery has been a lack of low-cost composite metals. Machined surfaces on low and medium carbon steel are expensive as compared with machine work on steel having 0·40% carbon, and it is a fact that lubrication is difficult and wear unsatisfactory for rapidly moving parts made of low carbon steel. Building up such surfaces by manual or even automatic arc-welding machines is, in many cases, prohibitively expensive. On the other hand, if the parts are made of steel having the machining and wearing qualities of 0·40% carbon or more, it becomes necessary to preheat the machinery part in the welding operation to prevent it from cooling rapidly and cracking.

A notable example of this limitation in the building of welded steel machinery parts is the problem of making welded steel gear blanks. The rim needs to be 0·40% carbon steel or above, so that the gear tooth-cutting operation will be successful. The remainder of the gear blank may be medium carbon steel. The job of handling the welded type of gear blank and welding it while hot is so difficult that most manufacturers prefer to buy cast-steel blanks. If a line of bar stock were available from the steel mills, with, say, 50% of the thickness 0·40 to 0·50% carbon and the remainder in the 0·15 to 0·25% range, most manufacturers would make their own gear blanks by welding. The rim would be formed hot with the higher carbon on the outside. The assembly of the welded

* Consulting Engineer, Welding, Cleveland, Ohio.

The author of this paper received the third Grand Award, $8,852.94, of the $200,000 Program sponsored by the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, in which savings of $1,000,000,000 were shown available to industry by wider application of arc welding.

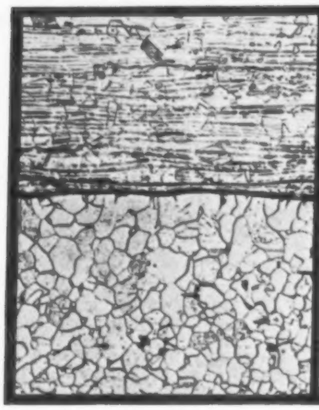

Fig. 2.—Completely processed stainless clad steel, 14-gauge sheets. Structure of 18-8 Mo clad sheet. In the photograph the dark bond may appear to be a separation of the two metals, but such is not the case. ×100. Etchants : Electrolytic chromic acid and 5% nital.

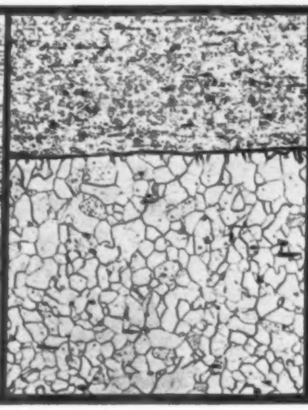

Fig. 3.—Completely processed stainless clad steel, 14-gauge sheets. Structure of 18-8 Cb clad sheet. ×100. Etchants : Electrolytic chromic acid and 5% nital.

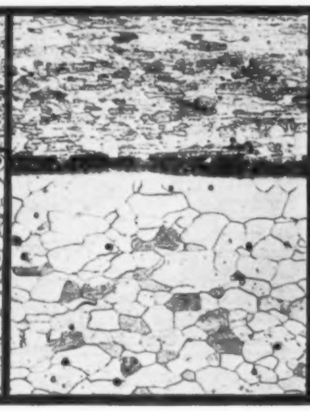

Fig. 4.—Completely processed stainless clad steel 14-gauge sheets. Micro-structure of 12% on chromium clad steel sheet, showing clad bond and base metal. The clad structure (top) consists of ferrite and carbides, and is typical of regular 12% chromium. The structure of the plain carbon base metal is normal. The bond consists of small ferrite grains with a large number of carbides. ×100. Etchants: Electrolytic chromic acid and 5% nital.

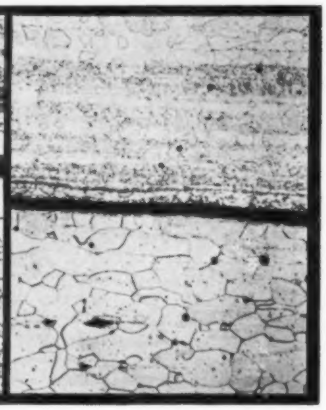

Fig. 5.—Completely processed stainless clad steel 14-gauge sheets. Micro-structure of 17% chromium clad steel sheet. The clad consists of ferrite and carbides, and with the exception of the laminated condition, is comparable to solid 17% chromium. The structure of the base metal (at bottom) is normal. The dark etching bond is similar to the bond of Plate 3, and is composed of ferrite and a large number of carbides. Etchants : Electrolytic chromic acid and 5% nital.

steel gear blank could then be made by welding on the low carbon side without preheating.

The above described composite would also be useful in welded steel machinery for guides, ways on planers, and in many other places on the machine where a surface is machined and subjected to wear.

The Need for a New Method of Making Composite Metal

When composite metals are to be fabricated, their usefulness is always a function of the quality of the bond between the component parts of the composite. Unless the bond is perfect, the metals separate in fabrication. Thus, plating alone is used *after* the metal has been formed, and all of the cold work completed on it. The bond is one of adhesion, not cohesion as in a weld. To get cohesion in a plated composite it must be hot-rolled.

A further necessity is a uniform and entirely complete bond between the components of the composite. Thus, even though 98% of the area of contact between the components is perfectly bonded by cohesion and the remaining 2% of area is held only by adhesion, the composite will be commercially unacceptable. Failure will occur when the composite is formed with the surface component in compression, or the defects will show up as blistering in service where the composite material is subjected to heat. A skillet made of a composite of carbon steel and stainless for the inside serves the purpose well if the bond is perfect and complete. But if the bond is not perfect and complete the stainless will blister because it has about two and a half times the coefficient of expansion and contraction of carbon steel. The point is well illustrated also in the case of stainless-lined oil-refinery vessels. While they give a satisfactory life in consideration of their cost, they fail by blistering between welds long before the lining itself is appreciably corroded. No low-cost composite metal meeting these requirements has heretofore been available, in spite of these obvious needs.

The requirement that the bond in composite metals is good for 100% of the area of contact is the first and most important necessity. The second need is that the composite shall be made by low-cost methods so that its manufacture and sale may be carried out to yield a profit to the maker.

Making Composite Metals in the Steel Producing Plant

The necessity for making the composites at low cost immediately indicates that the metal should be operated on as early in the basic process of manufacture as possible. Steel is made, rolled and processed by the most expensive machinery in order to handle it on a mass production basis and produce it at a cost which promotes its universal use. The conclusion cannot be escaped that the time to make the composite is while the metal is in the ingot or slab, or, in some cases, the billet form. If the metal is made composite here, it goes through all of the subsequent rolling and processing equipment which can handle it at high speed and low costs.

The contrasting cases of making nickel-clad steel and making electro-plated copper-clad steel, which is subsequently hot-rolled, illustrates the point. Nickel-clad steel is made by rolling together solid nickel slabs and steel slabs. A 1-in. thick nickel slab may be rolled on to a 9-in. thick steel slab. Thus, by working on 1 sq. ft. of steel 10 in. thick, 80 sq. ft. of 10% nickel-clad steel is obtained when it is rolled down to $\frac{1}{8}$ in. thickness. On the other hand, plating 0·013 in. of copper on 0·125 in. thick steel for subsequent hot-rolling would be entirely prohibitive in cost, because 80 times the area would have to be operated on.

The process and equipment hereinafter described is designed to work on ingots, slabs, or billets in the steel-producing plant and be further processed by existing equipment.

Composite Metals by Carbon Arc Welding*

In the steel-making process, the metal in the ingot stage represents the lowest cost of the metal in the solid state. Value is added by all the subsequent operations. It is most desirable, therefore, to make the composite when the metal is in the ingot stage, particularly by the process hereinafter described. Considering an ingot of low carbon steel, all that is needed to make it a composite is to add the necessary alloying elements to the metal on the surface to get the desired chemical analysis. This may be readily accomplished by carbon arc welding. It would be a round about and relatively expensive process to coat the surface of the ingot with the alloy desired in the form of a metal wire or rod using the metal electrode arc-welding process. Thus, in the making of a composite having an 18–8 stainless surface, in the case of carbon arc welding, it is only necessary to add ferro-chrome and nickel with an alloying element

* *Patents are pending on progress described.*

Fig. 6.—Completely processed 17% chromium clad steel, 14-gauge sheet. Structure of clad (top) is typical of the structure of 27% chromium. The bond is structureless. The grain growth in the open hearth steel was confined to the zone next to the bond. ×100. Etchants: Electrolytic chromic acid and 5% nital.

Fig. 7.—Micro-structure of semi-processed 18-8 clad steel half-plate hot rolled. Showing in greater detail the structure where the two metals join. ×750. Etchants: Electrolytic chromic acid and 5% nital.

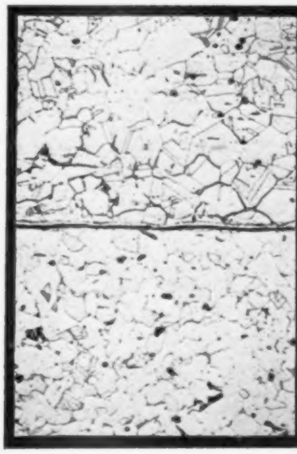

Fig. 8.—Micro-structures of completely processed 18-8 clad steel, 14-gauge sheets. Structure of clad bond and base metal. Heavy grain boundaries in clad near bond, indicate carbide precipitation. Structure of base metal is normal. ×100.

Fig. 9.—Micro-structures of completely processed 18-8 clad steel, 14-gauge sheets. Showing in greater detail the bond structure. ×500.

cost of about 8 cents per pound of 18–8 produced. Making an 18–8 surface by depositing 18–8 rod and metal arc welding would immediately involve a cost of 50 cents to 60 cents per pound for the stainless steel rod. In the latter case, the alloy is made and reduced to rod form suitable for welding, and heavy costs are involved. In the carbon arc method the stainless steel is made directly on the ingot, using the ingot metal itself as the base.

Experimental production of composite metals by carbon arc welding has been carried out over a period of two years. To avoid excessive cost of experimental apparatus, work has been done on slabs where the depth to which the surface alloying extended could be from ½ in. to 1 in. Large current supplying apparatus would have been required on thick ingots for a 20% depth of surface alloy. Such apparatus was not available for experimental purposes.

Fig. 1 shows the experimental equipment used. A Lincoln Tornado carbon arc head is mounted on the tool carriage of a planer. Motor and cam arrangement is provided to oscillate the head transversely to the direction of travel of the planer bed. The cam was designed empirically to give uniform distribution of the heat in operation, so that uniform depth of penetration of the alloy was the result. The cam turned out to be asymmetric due to factors which could not be calculated. Many slabs were sectioned, and the penetration measured and cam corrected accordingly. Current for the arc circuit was obtained from a Lincoln S.A.E. 800 ampere welder for thin alloy surfaces, and from a special motor-generator for currents up to 3,000 amperes for thick alloy surfaces.

The furnace mounted on the planer bed is provided for preheating the slab and working on it with the arc while it is hot. Adjustable speed is provided on the planer bed.

The operation for this experimental making of composite metals may be briefly described as follows :—

The slab (0·04% to 0·06% carbon, 0·20% to 0·30% manganese) is put in the furnace and suitable ground connection made to it. The alloy is applied in shallow pans. These pans are very thin low carbon steel and are melted in the process. The bottom of the pan is covered with the correct amount of alloy. In the case of making 18–8, ferro-chrome of the low carbon specification broken down to 10 mesh is used, together with nickel shot. Molybdenum, columbium, manganese may be added, depending on the grade of alloy wanted. The pan is then completely filled with slag, the height of the pan being designed so that when level full the right amount is present. This slag is composed of waste slag from an electric furnace in which 18–8 has been made, together with sand and calcium fluoride. The slab is now heated in the furnace with the alloy and slag in the proper location. An excess of slag is applied around the margin of the pans to keep the metal from flowing off the slab when the operation is in progress.

The slab is heated to a temperature of about 800° C. as determined by pyrometer with the top of the furnace covered. The carbon arc-welding operation is started after the cover has been partially removed, and proceeds from one end of the alloyed surface to the other. A 6-in. oscillation of the arc and 20 in. travel was found suitable for obtaining the specimens required for testing the composite material throughout the complete rolling and processing and final testing. On 2 in. thick slabs 1,800 amperes, 45 to 50 volts across the arc, 1·6 in. per min. planer-bed travel were found suitable. Under these conditions, the metal alloyed would stay molten from three-quarters to the total length of the travel, depending on the alloy being made. This was found to be a very important matter. After sectioning many alloyed slabs, it was shown conclusively that no failure of obtaining a perfect bond, over 100% of the area of contact, was ever encountered without striking evidence being visible on the surface.

Thus the process was developed to the point at which there could never be any uncertainty relative to this most important consideration. Any unusual condition resulting in the presence of blowholes or slag inclusions is immediately evident on the surface of the alloyed metal. This advantageous set of conditions would be predicted by anyone who had had experience with carbon arc welding under the conditions which this alloying is done.

After the alloying operation, the slab is removed from the furnace and cooled. The slag is easily removed when the slab is cool. The subsequent operations in the making of the finished product occur about as follows :—

The surface of the alloy is given a light grind to remove scale and uneven spots. The slab is then put in the heating furnace preparatory to rolling. In the case of the test slabs, the hot-rolling was first done to reduce and spread the alloy. The long dimension went into the rolls parallel

to the axis of the rolls. Rolling was done in two stages—first, down to about ½ in. thickness and allowed to cool. Later, the material was hot-rolled on down to ⅜ in., $\frac{3}{16}$ in., 14 gauge. The material was then annealed and pickled, and in some cases cold-reduced down as low as 20 gauge.

No serious difficulty was encountered in rolling operations. Some special handling is required on account of the unavoidable tendency to curl, due to difference in contraction coefficient of the two metals forming the composite.

Results of Chemical Analysis

There is given herewith typical chemical analysis of the alloy component of the composites made by carbon arc welding by the methods described. It is fairly obvious that the process is controllable to produce alloys in the form of composites within predetermined specifications. While the experimental apparatus was crude and difficult to control, every cause of variation was explored and the difficulties corrected in the design of the commercial equipment are described.

TYPICAL ANALYSIS DATA ON SURFACE ALLOYED SLABS.
ANALYSIS OF SURFACE.

TABLE I.

18–8 20% Cladding 2 in. Slab.

C	Cr	Ni	Preheat	Speed in. per min.	Current Amp.	Arc Voltage.
0·08	17·52	8·52	800° C.	1·55	1,800	44
0·08	18·60	8·23	800° C.	1·61	1,800	45
0·06	18·36	8·92	800° C.	1·52	1,800	49
0·07	17·6	8·07	800° C.	1·53	1,800	45

TABLE II.

18–8 Molybdenum

C	Cr	Ni	Mo	Mn	Preheat	Speed in. per min.	Current Amp.	Arc Voltage.
0·06	18·21	9·34	2·70	1·28	800° C.	1·55	1,800	49
0·06	18·20	9·34	2·40	1·16	800° C.	1·51	1,800	49
0·07	19·86	10·68	3·10	1·38	800° C.	1·52	1,800	45
0·08	19·22	9·41	2·60	1·90	800° C.	1·50	1,800	45

TABLE III.

C	Cr	Preheat	Speed in. per min.	Current Amps.	Arc Voltage.
		12 Cr			
0·09	11·97	800° C.	1·6	1,800	43
0·08	12·59	800° C.	1·6	1,800	42
		17 Cr			
0·09	18·33	800° C.	1·71	1,800	44
0·06	17·28	800° C.	1·7	1,800	45
		26 Cr			
0·12	25·08	800° C.	1·68	1,800	45
0·09	29·6	800° C.	1·71	1,800	44

Physical Nature of the Bond

There are reproduced herewith photomicrographs showing the nature of the bond between low carbon steel and 18–8, as well as the condition of the metals forming the composite. The illustration showing the carbon steel etched away from the stainless shows the most desirable physical contour of the bond. It will be noted from the actual specimen furnished that the bond does not occur in a smooth plane. An apt analogy is the case of two optical flats wrung together. They cannot be separated by tension normal to the bonded surfaces, but may be slipped apart. The non-planer bond in this composite metal is entirely free from this defect of bonding. The illustration showing the presumably martensitic structure in a very thin layer at the bond is characteristic of the process. That this layer in the bond does not affect the physical behaviour is shown by the bent and severely deformed material. Many tests have been carried out in an attempt to break the composite metals apart in the bond. None has been successful.

The most severe test in the stainless carbon steel composite is the blister test, where local heat is applied to the stainless side with an oxy-acetylene blowpipe. The slightest defect in bond will result in a blister where the metal is heated. No such defects have been found.

The reason for this perfect score is very simple. Had something gone wrong in the alloying operation it would have been immediately discovered, and the defect repaired by metal arc welding, using a stainless rod before the metal was rolled. There are no defects in the rolled metal, for the reason that it would not have been rolled had there been any defects present. Further, in the case of 18–8, the martensitic structure in the bond is stronger than either the normal stainless or the carbon steel. It would not be expected that the stronger metal would break before the weaker.

Cost of Composite Metals made by Carbon Arc Welding

The factors which comprise the total cost of making composite metal by this method are ones with which steel mills are accustomed to deal, so that cost of the product may be easily calculated. Thus, the alloy cost for the 18% chromium, 8% nickel metal is roughly 8 cents per pound. One 2,500 ampere carbon arc will make about 2½ lb. of the alloy on the surface of a pre-heated slab per min. The power taken from the line is about 1·2 k.w.h. per pound of alloy made. Carbon electrodes, slag, etc., are almost a negligible factor in the cost. Cost of pre-heating slabs may vary from $2·00 to $5·00 per ton.

The out-of-pocket cost of material, heat, power and labour, obtain a 20% cladding of 18–8 on low carbon steel and hot-rolling is of the order of $104·00 per ton of composite. The cost of making the alloy on the surface of the slab is approximately 15 cents per pound for 18% chromium and 8% nickel. Of the total of 15 cents per pound for this alloy, approximately 8 cents is for ferro-chrome and nickel shot; the remainder being the cost of operating the process. The 18–8 metal, being the most expensive ordinarily used, represents the highest costs.

For costs of processing the composite beyond hot-rolling a great deal depends on what is required. Pickling, grit-blasting, cold reduction, polishing or other operations may be carried out at usual costs for these operations.

Adaptability of the Process

A particular feature of the process is that it may be used by a steel-producing plant which is not equipped with an electric furnace and trained personnel to produce solid stainless steel.

Since both the thickness of the slab worked on and the thickness of the alloy applied may be varied, the process is adaptable to the production of composite metals having a very thin coating of alloy. Perfection of the modern cold reduction process has opened up possibilities of a composite made of low carbon steel with a very thin coating of perhaps 17% chromium on one or both sides. Tin plate with as much as 40 lb. of tin per ton is a high-grade product, but it seems quite likely that the same steel with 40 lb. per ton of 17% chromium on the surface would offer longer life and better corrosion resistance. The same conditions apply to a comparison with galvanised steel. With an out-of-pocket cost of applying 17% chromium of the order of 10 cents per pound and an extra cost for grit-blasting or belt-grinding before pickling where the cladding is applied to only one side, the cost of the composite is still comparable to the cost of tin plate.

Forthcoming Meetings

ROYAL AERONAUTICAL SOCIETY.

Mar. 30. "The Problem of Ancillary Power Services for Aircraft," by F. Nixon, B.Sc., and R. H. Chaplin, B.Sc.

April 20. "Possible Steel Developments for Aircraft," by Dr. T. Swinden.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Mar. 30. "Some Observations on the Freezing of Cast Iron," by J. E. Hurst.

SWANSEA SECTION.

Mar. 21. "Developments in Apparatus for Metallurgical Research," by Dr. J. L. Haughton.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Mar. 24. "The Strength of Marine Engine Shafting," by Dr. S. F. Dorey.

April 21. "The Ideal Design of an All-Welded Ship," by J. P. Wadling.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
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The Trade Barometer

SEVERAL factors evident during the past few weeks have raised hopes of recovery in British industry and contributed to a feeling of greater confidence in the solution of international differences. Probably the most noteworthy of these was the remarkable drop of 143,000 in the number of unemployed given in the February returns as compared with those of January. The good showing last month reflects to some extent occupations adversely affected by the weather in January, but in comparison with a year ago the employment figures show a rise of 70,000, and the fall in unemployment was considerably greater than the seasonal decline usually experienced in that month. Practically all industries contributed to this improvement; the iron and steel industry in particular showed employment progress for the second month in succession, and the prospects for March are bright. Not since March last year, when 1,115,800 tons were produced, has the British iron and steel industry reached the production figure of 971,000 tons of steel ingots and castings attained last month.

Improved conditions also exist in the non-ferrous metals industry, particularly in the aluminium industry, where the defence programme is making increasing demands on producers and manufacturers. February has shown an upward trend, and the prospects are good that further progress will be made this month, not only in meeting the requirements of the home market, but in exports to overseas markets. Metals prices are maintaining a steady tone, with the tendency to rise slightly.

Another fact which has provided a brighter outlook is the optimism prevalent as a result of the British Industries Fair. Remarkable results attained at this Fair, combined with many gratifying and important contacts with overseas buyers, are creating a wave of confidence that this year will prove a prosperous year for British industry. The Fair attracted over 7,000 buyers from overseas, whose purchases and orders were on a big scale. This desire to trade with Britain is naturally viewed as an indication that the international situation is greatly improved, and that the anxieties which checked buying in 1938 have been displaced by greater confidence.

A useful indication of revival is the pronounced and all-round improvement in prices of stocks and shares. There has been a revival of interest in recent weeks, and a movement is in progress which is regarded on the Stock Exchange as an upward phase associated with recovery. Industrials generally show good progress, and these, together with the sharp rise in bank advances, strengthen the impression of an all-round revival, unfortunately, however, financial matters are so easily influenced by political changes.

It was confidently thought that the political situation was genuinely improved and that confidence in that direction was gradually being restored, but recent happenings do little to foster that condition. It is gradually being recognised abroad, however, that Britain's growing defence programme, the able manner in which it is being tackled and the enormous sums which the House of Commons is voting to it, is not designed for aggression against any country, but to ensure that Britain is in a position to defend herself against aggressors. There is every indication that this programme is proceeding with energy and efficiency, and this fact is probably contributing to the general feeling that outstanding political problems can and will be solved peaceably.

With the early termination of hostilities in Spain, it will be surprising if a conference is not arranged to discuss some of these problems, and with their solution the way would be open to discuss some form of limitation in armaments. Italy has made it clear that she has no territorial ambitions in Spain and that her volunteers and advisers will be withdrawn as soon as the war is over. A Franco-Italian settlement will be the first objective on the conclusion of hostilities in Spain, then it will be possible to examine the wider European problems with a view to an early settlement. It should be remembered that the desire of all the peoples of the world still remains centred in the hopes of peace and a return to the atmosphere of understanding and good will which has so often been disturbed.

It was thought that a solution to some of the problems associated with export trade would result from the meetings arranged between British and German trade representatives to discuss Anglo-German trade. Unfortunately recent events have caused the cancellation of these trade talks that were planned. Whether an arrangement would have been possible, had the talks taken place, is extremely doubtful, as although there is no lack of good will in Germany, her problems are not unlike our own; Germany must export to balance her overseas payments, and in that respect she does not differ from Great Britain.

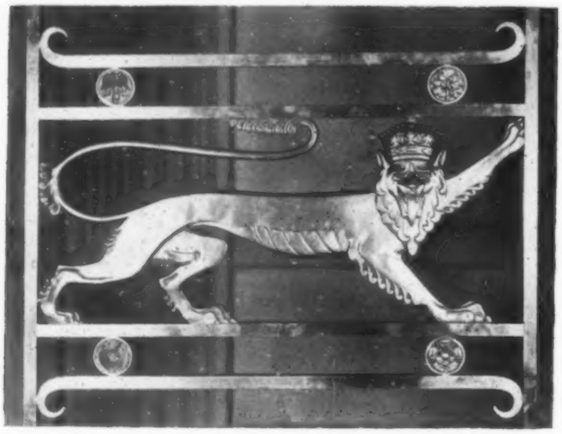
Unfortunately, since the Great War the world's markets have been shrinking, and the pressure of competition each country has felt from the other is due to this fact. Obviously, if the world could absorb all the manufactured products both countries have to export, no problems would arise. An expansion of the world market to a degree that would enable each country to export to the extent of its necessities is the one development that would entirely remove economic friction between the two countries. This would be an achievement of the first order, but of doubtful possibility. The problems involved seem to be too big to be solved by friendly talks. The question of subsidies, for instance, which is frowned upon in this country, is regarded as essential to Germany, and provides one of the methods by which she is able to compete. But it is claimed by German firms that they pay more into a common fund for this purpose than they obtain in subsidies. Thus it seems that all export trade is conducted at a loss, even when subsidised. Discussions on trade matters are arranged to take place in Warsaw and Moscow which are expected to strengthen the political ties with these capitals and facilitate trade between Britain and Poland and the U.S.S.R.

Sufficient has been said to show that while the trade barometer has shown a tendency to rise, the political position is not by any means sufficiently stable to warrant optimism regarding an immediate recovery. The obstacles to the expansion of world trade are still very formidable and it is greater confidence in the political situation which is so necessary to facilitate recovery and to the promotion of a period of prosperity. This can only be satisfactorily achieved by peaceful methods.

New York World's Fair

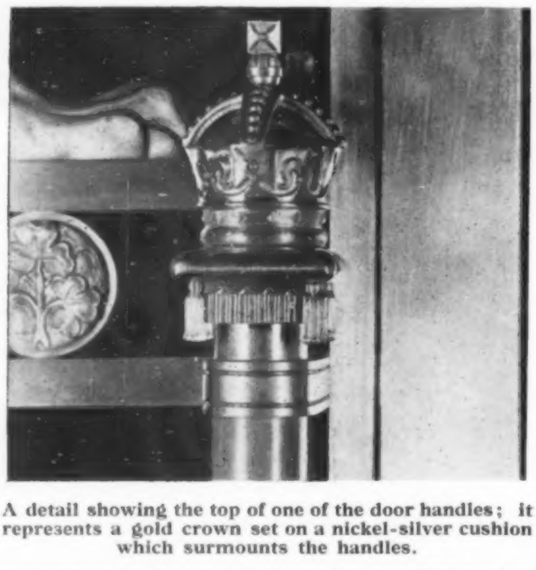
THE New York World's Fair opens on April 30 next, the 150th anniversary of the inauguration of America's first President. The theme of the exhibition is "Building the World of To-morrow," and will cover past, present and future activities in science, arts, administration, industry, transportation, housing, etc. The Fair will be international in spirit and some sixty nations will be represented.

The official exhibit of the United Kingdom will be on a large scale and will derive added interest from the close



The principal motif in the design of the doors for the British Pavilion at the New York World's Fair. The lion is cast in bronze.

and friendly relations existing between Great Britain and America and from the forthcoming visit of the King and Queen to America. Exhibits will show in graphic form incidents from the common past in which both these English-speaking nations have their roots. Other exhibits will show the varied public services of the United Kingdom, and trade will be represented by exhibits showing the

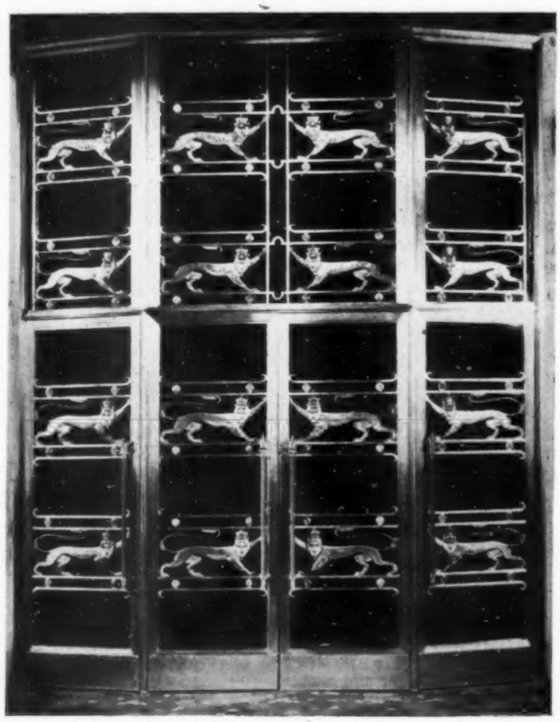


A detail showing the top of one of the door handles; it represents a gold crown set on a nickel-silver cushion which surmounts the handles.

country's part in the maritime, textile, metal, aircraft, and many other industries. Sections will be devoted to modern architecture and contemporary art, and to the attractions of Britain.

The United Kingdom exhibit occupies two pavilions connected by a bridge, the South Pavilion of which is the grand vestibule to the larger North Pavilion. Access is given to the South Pavilion by a double outside staircase in an open loggia, dominating the great open lagoon which is the Square of Honour leading to the American Government Buildings. Two sets of nickel-silver doors will lead to the two circular vestibules which are the twin entries to the series of apartments forming the Court of Honour in which will be an elaborate display of heraldry.

These doors, which have been presented by the Mond Nickel Co., Ltd., were designed by Stanley Hall and Easton and Robertson, the architects for the British Pavilion, and executed by J. Starkie Gardner, Ltd. Each set comprises four pivot-hung doors surmounted by a fixed head. The overall height of the doorway is 14 ft. and the width 12 ft. The weight of each set is $1\frac{1}{2}$ tons. They are executed in Wiggin 20% nickel-silver, enriched with cast-bronze lions, which form the principal motif, repeated in each door and in the fixed head. The bronze lions are supported on nickel-silver bars, which are secured on rosettes cast in nickel-silver and bearing simple representations of the national emblems of England, Scotland, Wales and Ireland. The door handles are surmounted by a gold crown and terminate at the bottom in a cast nickel-silver tassel. The doors are glazed with clear polished plate glass.



A general view of one of the two sets of doors for the British Pavilion. The doors are executed in Wiggin 20% nickel silver.

It is noteworthy that these doors are built largely from extruded sections. It is only in recent years that 20% nickel-silver, which has considerable strength, could be extruded; a new extrusion press, recently put down by Henry Wiggin and Co., Ltd., has made extruded sections in this alloy commercially available.

By the courtesy of the Mond Nickel Co. we were able to see a set of these doors erected before their shipment to New York, and we were particularly struck with the simplicity of the design, yet dignified, befitting a Pavilion representing the British nation. The attractive soft colour of the nickel-silver, brought out by a satin finish, give the doors a truly regal appearance, and they should prove of great interest to many who visit the Fair.

Messrs. C. H. Mountford, 508, Bromford Lane, Birmingham 8, we are advised, have been offically appointed representatives for the British Isles for Friedrich Deckel, Munich, Germany, for the sale of universal tool milling machine Type F.P.1, universal mould and die milling machine Type G.K., letter engraving machine Type G., and universal tool grinding machine Type S.1.

Progress in Aluminium Alloy Founding

By K. W. Keeble
(*Works Metallurgist, William Mills, Ltd.*)

Some of the difficulties encountered in the production of aluminium alloy castings are discussed, and the lines along which development and research work are proceeding are outlined. The author briefly discusses new alloys for casting purposes; free machining alloys; aluminium silicon alloys; chemical analysis; foundry technique; non-destructive testing of castings; assessment of foundry properties of casting alloys; and secondary aluminium alloys.

ALUMINIUM alloy castings are available from sand, gravity, and pressure casting processes. The choice of the best alloy and the decision as to whether sand or die-casting methods are applicable depend upon the character of the casting, its service conditions, and the quantity required.

In its pure state aluminium possesses poor foundry properties and low mechanical strength values. Only castings of simple design and for purposes where electrical or chemical properties are of prime importance are made in the pure material. In the early days the casting alloys most used appear to have been those containing high percentages of zinc. Then followed the introduction of the copper-bearing alloys. During the Great War the first heat-treatable alloy in the form of the famous "Y" material was developed as a casting alloy suitable for high-temperature work in the form of pistons and cylinder heads. Then followed the appearance of the modified silicon alloy series. The famous RR series of alloys was then introduced, and these were followed by further development of the silicon aluminium series with minor additions to render the alloys amenable to heat-treatment. A large number of the current alloys require to be heat-treated to give their optimum properties. As in steel practice various forms of heat-treatment may be applied to obtain different combinations of mechanical properties.

The lines along which research and development work are proceeding in the aluminium alloy founding industry are outlined in the following notes.

New Alloys for Casting Purposes

So many factors have to be taken into consideration that the commercial development of a new casting alloy must be preceded by an immense amount of experimental work, first of all on a laboratory scale and then on a practical scale in the foundry.

The attainment of high elastic and ultimate strength properties has until recently been the tendency. While ductility is generally only of secondary importance in a casting, there has lately been a demand for an improvement in this respect. This has resulted in the development of a medium-strength type of casting alloy having substantially greater ductility.

Three types of alloy are in common use in which the principal alloying additions are copper, silicon and zinc. These alloys may have further additions of a second of the above elements and/or amounts of magnesium, manganese, nickel, iron, etc. Increasing attention is being directed to the development of magnesium as a main alloying element. The physical properties and corrosion resistance of this series are quite attractive.

Grain refining agents, such as cerium, boron and titanium, are being increasingly used, especially in the alloys which respond to heat-treatment. Small quantities of iron and silicon are normally present in all commercial grades of aluminium. Work on the copper-aluminium and magnesium-aluminium binary systems has demonstrated that these materials have outstanding strength properties after heat-treatment when made with controlled amounts of the iron and silicon impurities. Alloys covered by specifications DTD. 298, 300, 304, and 361 are examples of this development.

It seems probable that closer attention to the regulation of the minor impurities in casting alloys may give worth-while results. Super-purity aluminium is now available with an analysis of 99·99% aluminium. This material provides the metallurgist with an ideal base for investigation of the effects of specific additions of impurities.

Aluminium Alloy Casting for Internal Combustion Engines

In the case of the aero engine the maximum power output, expressed as horse-power per unit of cylinder capacity, has increased over the last seven years by amounts varying between 50 and 100% according to type. Similar development in engine performance has also taken place in the automobile sphere. Increased power output means more heat to be dissipated with the exhaust gases and by conduction through the cylinder unit components. In the case of air-cooled engines, the fin area of the cylinder head and cylinder body has been considerably increased to improve heat outflow conditions. Where cylinder head castings are concerned, the increased depth and thinness of the fins in conjunction with the fairly thick and involved sections of the combustion chamber and ports problems arise which only foundries of the requisite experience and facilities can solve.

The production, as gravity die castings, of water-cooled cylinder heads for the automobile industry is a sphere of casting activity which demonstrates the resource and ingenuity of the specialist foundryman. In addition to the obvious need of first-class patterns and foundry-box tackle, close control of mould and core positionings by templets, mould and core hardness, pouring temperature, etc., has to be exercised to achieve the dimensional accuracy which is demanded in certain types of liquid-cooled cylinder block castings.

Power output of the petrol engine, particularly on the aviation types, has been increased to a value which may involve the centre of the piston crown approaching a temperature of 450° C., according to one authority.[1] Under present conditions, the limiting factor on output of high-efficiency petrol engines may be the working strength value of the piston design. Present heat-treated piston alloys are :—

(*a*) 10% copper alloy with small amounts of iron and magnesium.
(*b*) The Y and RR series, containing nickel, copper, iron, magnesium, and silicon additions.
(*c*) The 12% silicon alloy, with nickel, copper, iron and magnesium additions.

After suitable heat-treatment these alloys will give Brinell hardness figures which average 120 to 140. This hardness is reduced by the annealing effect of service running, but the gudgeon-pin bosses and skirt derive permanent benefit from such a treatment. There is a tendency to adopt a heat-treatment schedule which includes a final stabilising treatment at 200° to 300° C. Its purpose

(1) Autumn lecture to Institute Metals, 1937, by Dr. Pye, on "Metallurgy and the Aero Engine."

is to relieve internal stress and allow the "growth" property to proceed to completion. In large Diesel type engines, where aluminium alloy pistons weighing up to 5 cwt. approximately and 20 in. or more in diameter are used, the question of internal stress assumes a position of considerable importance. For this reason the heat-treatment applied involves a semi-anneal operation which gives a final Brinell hardness in the region of 80.

The coefficient of expansion of aluminium progressively decreases as the silicon content rises. For the alloy (*c*) over the range 20° to 300° C. this value is 0·000021 and is some 0·000003 less than that obtained with other alloys. In practice, this feature means decreased clearances, which in turn gives cooler running and increased power output. From the foundry viewpoint the alloy is attractive because it is fluid and has good casting properties.

Free Machining Alloys

It is interesting to record that the development of free-cutting aluminium casting alloy has not attracted the attention the subject merits. Summarising the existing situation, thermal and mechanical working of a suitable composition is used for the production of a free-cutting structure in wrought alloys; whereas, for casting alloys, reliance is placed on securing the correct dispersion of an insoluble element by suitable foundry technique. In relation to aluminium casting alloys, the elements lead, bismuth, and cadmium have received attention. The alloy to specification DTD. 294 contains cadmium up to 2%. This element imparts excellent machining properties, together with increased corrosion resistance. Its strength properties, at 14 tons per sq. in. with 3% elongation minimum, make it a useful alloy.

Aluminium Silicon Alloys

The expiration of the patents covering the modification process as applied to silicion alloys has meant the entry of more foundries into the field of aluminium silicon alloy casting production. This material is the delight and despair of the founder at one and the same time. Its fluidity and freedom from hot-shortness are outstanding characteristics, whilst its shrink-cavity formation habit is an ever-present problem. The alloy is sensitive to the runner, riser and chill lay-out. Because it is used in the metastable state, the alloy should be purchased from a reliable source to ensure that the initial modification is uniform from ingot to ingot, otherwise trouble will quickly arise. Technical control is essential at the melting furnaces, for time and temperature limits must be closely observed, also modification technique must be adapted to suit furnace conditions.

Aluminium Alloy Chemical Analysis

Because of the increasing complexity of the composition of the high-strength alloys and impurity elements, which are occurring in the common casting alloys of secondary origin, analytical methods tend to become more involved. The use of organic reagents in light alloy analysis methods is extending. An example is the hydroxyquinone preparation.

Further progress has been made in developing the technique of quantitative spectrographic analysis. Briefly the spectrum of the sample is recorded on a photographic film. Then the intensity of the line of the element in question is compared with a neighbouring line in a comparison spectrum or its density measured by a photometer attachment. The advantages of the spectrographic method are:—

(*a*) Extreme rapidity.

b) The photographic film is a permanent picture of the composition to which reference can always be made.

(*c*) Sensitivity; the chance of overlooking the presence of an unsuspected element is small.

The main disadvantage appears to be its low order of accuracy, this being in the region of plus-and-minus 5%. Often a spectrographic analysis may reveal all the informal tion the metallurgist is seeking. Further, in commercia- practice, a large number of samples are checked to determine whether they fall within the limits of specifications. In these cases it seems that the spectrographic method, despite the low order of accuracy, offers useful possibilities particularly if the error range is known.

For certain aluminium alloy analytical work spectrographic technique has achieved commercial status.

General Foundry Technique

On the metal melting side of foundry activity there has been a steady assimilation of those factors which have been outlined in published research of the last decade. More attention is probably being applied to the minimisation of dross losses by efficient use of suitable fluxes. The introduction of grain-refining agents into the metal, such as titanium and boron via fluxing salts, has received some attention. The use of refractory compositions having thermal diffusivity values, approaching those of iron and copper alloys, have received a certain amount of investigation in relation to their use as chills or deneseners. The material is in a plastic condition, which can be moulded to the desired shape and then dried off prior to use. Chills in this material are not subject to sweating, with its attendant blowing troubles, as are those in metal.

More readiness on the part of the customer to accept amendment of his design in order to help the founder produce a better (and usually a cheaper) job is an increasing feature. Many customers have yet to realise that battered patterns with loose pieces having frayed locating points are not conducive to the production of a casting dimensionally satisfactory.

Non-destructive Testing of Aluminium Alloy Castings

Hitherto, the quality of batches of castings has been checked by subjecting selected samples to various forms of inspection. These tests included micro and macro examination and mechanical tests conducted on test-pieces cut from the casting walls. The use of methylene blue and the searching power of the anodising process are helpful in detecting certain types of porosity. Apart from assessing the efficiency of the heat-treatment process (if involved) the main purpose of these test methods is to determine the degree of soundness secured in the castings. Some of these examinat'on methods are necessarily destructive in effect, while others, in returning a negative result, do not necessarily indicate the casting to be free from locked-up gas holes or shrink cavities, which may be revealed on machining or never at all. The examination of castings by X-rays will reveal discontinuities of all types, without in any way being destructive in effect. Progressive foundries have already installed the necessary apparatus and production of castings to pass X-ray inspection is now routine procedure. Light alloy castings for aircraft against Air Ministry orders are divided into three classes, according to the importance of the casting. Castings under Class 1 *each* have to pass a radiological examination; and *a percentage* of those grouped in Class 2 category undergo X-ray inspection. Class 3 castings are freed from radiological examination.

In its application to aluminium alloy casting practice, testing by X-rays may be divided as follows:—

(*a*) Examination of atomic structure, including the measurement of internal stress.

(*b*) Examination of castings to detect flaws, such as porous area, blowholes, etc.

Method (*a*) is being increasingly used among other applications to measure the residual internal stresses which exist to varying degrees in all castings.

Radiological examination consists of passing radiant energy through the casting, and detecting the various intensities of the emergent beam by a photographic film or fluorescopic screen. The sensitivity of the process may

be expressed as a percentage of the thickness examined occupied by the smallest defect detectable on the radiographic picture. Some of the factors affecting sensitivity are controllable and are part of X-ray technique, whilst others are limitations associated with the apparatus being used. Fluoroscopic examination has a sensitivity value in the region of 5%. Fluoroscopy is useful for detecting the grosser type of defects, such as blowholes, turbulence cavities, and excessive shrink areas. It is a quick and relatively cheap method of non-destructive examination.

The radiographic procedure gives a permanent record of the density of the casting and sensitivity values around 1% are obtainable on the ordinary range of casting thicknesses. The main disadvantage, at present, of the radiographic process is the lack of service experience on which to base a correlation with the radiographic evidence. Patches of intense porosity or localised blowholes may be more weakening to a given casting than fine gas-hole porosity. There is a marked difference between castings which are technically unsound and those which are serviceable. In this respect great judgment is necessary in the use of radiology as an inspection process.

On the relationship between radiological soundness and mechanical strength of castings, much remains to be done. In an investigation on aluminium die-castings[2] it was found that the variation in mechanical properties from porosity was about 10%, which was less than that due to normal microstructure differences, which was of the order of 20%. These results suggest that in some cases the lower sensitivity of the screening process is adequate because only the large flaws have to be detected. Castings classed as doubtful on radiographic inspection because of porous areas, etc., have been passed as satisfactory in most cases in the writer's experience when subjected to static breakdown tests. Where the customer can help the founder and himself is to indicate on the drawings the highly stressed areas, so that intelligent correlation may be made of radiographic features with the stress distribution in the casting. In certain quarters this procedure is already being followed.

The modern aluminium alloy founder is making good use of radiology to improve his product. The casting user, in turn, should establish a background of experience which can link up the radiographic evidence with service life.

Assessment of Foundry Properties of Alloys

The casting properties of an alloy have a direct relationship to the soundness of the casting. The assessment of the casting characteristics of an alloy in quantitative terms is a very difficult task. The factors which govern these characteristics are complex and closely interrelated. The properties involved mainly are the flowing power and hot-shortness.

(*a*) *Flowing Power*.—The terms " liquidity," " fluidity," " life," etc., have been used to describe a property of the alloy which may be defined as the ability of the metal to fill a mould. It is becoming accepted that the term " flowing power " is more correct as a name for this property. Flowing power depends upon what may be termed " external " and " internal " conditions. The mould material, with its temperature and facing, the pouring head and the metal superheat may be grouped as " external " conditions. The " internal " conditions include surface tension, surface oxide films, gas content, suspended inclusions, composition, freezing range, and thermal properties. Factors in both groups are under investigation. The most popular method of determining flowing power values is to use some form of spiral test mould. Whilst flowing power is a property of all casting metals, it is particularly sensitive in light alloys because of their physical and chemical properties.

(*b*) "*Hot-shortness*."—When applied to wrought processes, this term involves the intrinsic hot strength of the alloy—i.e., its resistance to hot working without showing brittle failures. The applied stress is governed by the conditions of working, and is not a quality of the material. When applied to the cast process, " hot-shortness " infers hot strength and a stress which in this case is applied internally from thermal contraction effects. In this case the stress applied is probably an inherent characteristic of the metal in cracking, whereas it is not so in hot-working behaviour. By the use of suitable shapes, such as a ring or tee-piece, etc., various attempts have been made to determine quantitatively " hot-shortness " values. The test castings are poured under regulated conditions of some form of restricted cooling.

In castings, the liability of hot-shortness cracking occurring is bound up with the freezing shrinkage, rate of contraction, and hot strength of alloy as metal factors with efficiency of feeding, also mould friction and rigidity as mould factors. The latter group is of particular importance in permanent mould work. According to the complexity of design, hindered contraction may be operating which may set up internal stresses and not be sufficiently intense to cause an actual hot-shortness rupture. This condition appears to be why certain castings can be made in a low-grade alloy while others crack, etc., when made in similar material. This " quality " aspect of alloys is briefly surveyed in the following section.

Secondary Aluminium Alloy

The first cost of aluminium metal makes its subsequent reclamation wherever possible an economic desirability. Aluminium metal and alloy scrap may be grouped into two classes : (*a*) Process scrap and (*b*) market scrap. Process scrap is that which occurs during the production of finished or semi-finished manufactures and which is reabsorbed internally at the plants. Market scrap is that which is normally available to the secondary metal people. It is composed of sheet cuttings, old rolled scrap, machine-shop swarf, scrap castings, foundry dross, residues, etc. From this material, with hardener alloys and pure primary aluminium, casting alloys are produced to compete against those made of virgin materials.

One of the criterions of quality of secondary alloys is composition. A characteristic of most secondary products is that while the normal alloying elements may be within the specification range, usually there will be found small amounts of other elements. This is hardly surprising when the character of the raw materials used is considered. All aluminium alloy founders are acquainted with the mysterious bouts of cracking and drawing troubles which afflict running patterns and which appear and disappear in a most bewildering manner. The possible causes are many, but experience indicates that the use by the foundryman of the adjectives " tired " and " poisoned " (among others equally descriptive) in relation to the metal is often justified.

The interrelation of certain of the impurities are little understood. These unexplained and disturbing outbursts of trouble may be connected with the presence of metallic impurities in certain concentrations, the effects on the casting properties of which have not been established There is also the question of non-metallic inclusions in this class of material. The remedy in such cases of trouble is to withdraw all the affected material out of the metal circulation and recommence with fresh material, virgin quality, if possible. The withdrawn material may then be slowly diluted back into circulation.

Where high quality castings are required and where castings have complex bracketing, etc., it is highly desirable to use virgin metal, and its own process scrap. The microstructure changes resulting from the heat-treatment depend for their functioning on a closely controlled composition. Heat-treated castings are intended to be highly atressed components. In such cases it is necessary that the reliability of composition, etc., characteristic of virgin alloy, be utilised to the fullest extent.

2 Frommer, Kuntze and Sachs. " Zeitschrift des Vereins deutscher Ingenieure," 1929, Vol. 73, page 1609.

Corrosion-Resistant Materials and Soap-Making Plant

CORROSION-RESISTANT materials are of vital importance in the soapmaking and allied industries, and much of the equipment calls for the use of fairly heavy plates. The equipment in such plants is large, and the economic application of material has been made possible by the adoption of stainless steels and of steel clad with nickel, Inconel, and other materials with outstanding corrosion-resisting properties.

The saponification process in soapmaking involves reaction between alkali and fatty oils or glycerides, fatty acids, or a mixture of both. The fatty acids may be either of animal or vegetable origin, occurring as complex fatty oils—generally the glycerides of organic fatty acids. In producing fatty acids, the first essential is to break down the glycerides into their glycerol and fatty acid constituents, the hydrolitic process employed being known as splitting. This process is carried out at high temperature, and there is now a trend towards the use of autoclave splitting at higher temperatures and pressures than formerly. Tests have been carried out to determine the degree of corrosion on materials suited for the processing of fatty acids, oils, and soaps.* The results were separated into two classifications—the processing of fatty acids and the manufacture of soap,—and provide a useful guide to the selection of suitable materials for the equipment of soapmaking and fatty acid treating plant.

A pertinent point noted was that in some equipment obsolescence might be a more significant factor than actual corrosion rate: thus when obsolescence is likely to determine the life of any piece of equipment, it may be preferable to specify the least costly material, and there is the very important factor that, even though the corrosion rate of one material be higher than another, that material might be more suitable for some purposes on account of the fact that the products of corrosion may be less harmful to the material being processed. It is an involved question, but extensive tests have clarified the position, assisting the designer in his choice of material.

Oils, fats, fatty acids, and caustic alkalis are stored in tanks made of corrosion-resisting materials; nickel is highly resistant to corrosion by sodium hydroxide and is preferred for the handling of caustic; nickel evaporators are widely used for the manufacture of sodium and potassium hydroxides; and "Ni-Resist" is used for equipment such as pumps and heavy castings. In soapmaking the product needs protection against discolouration: soap-boiling kettles are made from nickel-clad steel, steam jets or coils being of nickel or Monel. Nickel, Inconel, Monel, and Ni-Resist have been found to be strongly resistant to corrosion by the acid and caustic treatment of spent lye; nickel is used for pipes and evaporator tubes, and nickel-clad steel for tanks and evaporator bodies; nickel-clad steel is also used for brine tanks in some plants where the salt is added to soap kettles as a concentrated brine solution, and pure nickel tubing is adopted in brine pumping systems.

Monel, nickel, and nickel-clad steel have been used successfully for such details of soapmaking and acid-treating plant as crutchers, cutters, frames, mixers, dies, pipes, wrapping tables, and plodders, and it is interesting to note that at least one manufacturer found satisfaction by using cold-rolled, three-quarter hard Inconel strip running against stainless steel and chromium-plated rolls for the doctor blades on drying or chipping rolls.

In some processes ordinary steel would apparently be adequate for corrosion resistance, but the necessity for avoiding iron contamination of the contents makes it advisable to use a nickel-clad steel. This applies, for example, in the separation following the fat-splitting process, and involving glycerol storage and bleaching by the use of activated carbon.

The tests also showed that even small quantities of certain alloying elements have a major effect in improving the resistance of cast iron to fatty acid corrosion. For example, a 3% nickel addition, with or without a small inclusion of chromium, provides approximately twice the corrosion resistance of plain cast iron, and these low-alloyed cast irons do not suffer graphitic corrosion to the same extent as plain iron. It is stated that probably the duration of cast iron used in fatty acid distillation plant is largely determined by the protection afforded by graphite layers when they have become sufficiently impervious to prevent progressive attack. Ni-Resist was quoted as specially suitable in this direction, plus the advantage of availability in cast shapes at relatively low cost.

It is evident that the choice of materials is also influenced by such properties as amenability to fabrication and mechanical qualities.

* *Ind. Eng. Chem.* 30. 12. 1350.

Influence of Small Metallic Additions to Refined Aluminium on Tensile Strength, Corrosion Resistance, and the Formation of Protective Films

REFINED aluminium of a purity of more than 99·99% has been produced under normal conditions for about a year. It differs from the usual primary aluminium, containing 99·5 to 99·8% aluminium, by its high plasticity, by its resistance to the corrosion of many agents, and by its low tensile strength. For many purposes the first two properties are very important, but the low mechanical property often makes its use difficult. Extensive investigations have been made by Hans Schick and Werner Helling, with the object of determining the influence of small additions of metallic elements on the strength and corrosion resistance of refined aluminium. The experiments included addition of Si and Fe up to 1·5%; Cu up to 0·1%; Mg up to 5%; and Ti of 0·11 to 0·12%. It is known that refined aluminium has a better welding seam corrosion resistance than primary aluminium, and that the additions used in the experiments mentioned have a great influence on the appearance of anodised films.

As the result of the investigations, the authors found that Si and Fe, up to a content of 0·07% have no unfavourable influence on the corrosion resistance against oxidic solution of sodium chloride, but it is known that a Cu content of 0·005% is detrimental under similar conditions. Alloys containing Mg, produced from refined aluminium, are thoroughly constant in oxidic solution of sodium chloride and clearly superior to those produced from primary aluminium. The same difference could be observed with alloys containing Ti. Corrosion at the weld changes, but Si and Fe contents of more than 0·3% and Cu contents up to 0·1% have no influence on the durability of the weld against sulphuric and nitric acids. Alloys of Mg are constant up to a Mg content of 3%.

Additions of Si, Fe, and Ti have an unfavourable influence on the formation of films produced by the anodic treatment; the brightness of the film began to diminish at a content of 0·044%. Fe starts to make trouble at contents of over 0·2%. The addition of 0·11% Ti leads to a light dimness of the film; Cu, however, up to 0·1% does not result in any change. No graining takes place. At additions of Cu of 0·001 and more the thickness of the film increases considerably, the tint begins to be somewhat warmer and reminds one of the brightness of nickel.

It is possible to produce highly polished films of anodised aluminium in all Mg alloys manufactured from refined aluminium. In contrast to the normal aluminium-magnesium specimens, graining does not take place. These alloys should be very suitable, when a bright anodised film and complete absence of graining is indispensable. In comparison with unalloyed refined aluminium, these alloys also have the advantage of high tensile strength.

Nickel in the Non-Ferrous Foundry

By F. HUDSON

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IN looking back over the last decade on foundry progress the impression is left that, in general and excluding the phenomenal rise of the light-alloy casting industry, the non-ferrous founder has not progressed to the same extent as his brethren in the iron and steel industry. The reason for this is not far to seek. In the first place, remarkable strides have taken place in the ferrous trade since the advent of alloy steels and alloy-cast irons. This has resulted not only in an improved product of greater interest to the user, but a product having greater interest to the founder himself. Consider the case of alloy cast iron, the inception of which called for increased technical control and the installation of more efficient practical methods of production. These factors alone have improved the status of the iron founder, while a point of great importance has resulted from the active interest shown by workers in this field in outlining developments and airing problems through various mediums. It is noteworthy that the latter has been contributed by the more technical worker.

Under the circumstances, it is suggested that in order to increase the status of the non-ferrous casting industry as a whole, a guide may be taken from the work of the iron founder by considering the practical development of newer and more modern alloys. Improved technical control would be a natural sequence, and this, in turn, would provide an outlet for a greater sphere of non-ferrous activities. Alloy additions to non-ferrous metals are becoming increasingly important. Nickel, chromium and beryllium, together with other alloys are playing increasingly important roles in the production of high-duty non-ferrous castings. The purpose of this discussion is to outline foundry practice relative to the more recent advances in non-ferrous metallurgy as applied to a typical modern alloy. The alloy selected for this purpose is the high-duty bronze containing 5% nickel, 5% tin, 2% zinc, balance copper.

Bronze Containing 5% Ni, 5% Sn, 2%Zn, Bal. Cu

The composition of this alloy resembles Admiralty gunmetal, excepting that 5% of tin has been replaced by 5% of nickel, and it is of interest since it is susceptible to heat-treatment, permitting castings to be produced having mechanical properties similar to high tensile brass. In composition the alloy is not new. In 1923 a British patent[1], now expired, was granted putting forward the cast material as being very suitable for use with superheated steam up to 500° C.

It was not until 1931 that the possibility of improving the mechanical properties of the alloy by heat-treatment was discovered in the United States by Wise[2]. This development has since been fully outlined by Wise and Eash[3] in a paper given in 1934, and more recently by Kihlgren[4] this year. Briefly speaking, it has been found that a bronze containing 5% nickel, 5% tin, 2% zinc, when melted and cast with good foundry technique has mechanical properties, before and after heat-treatment, as shown by Table I.

It will be observed that "as cast" the alloy yields properties somewhat superior to those normally obtained

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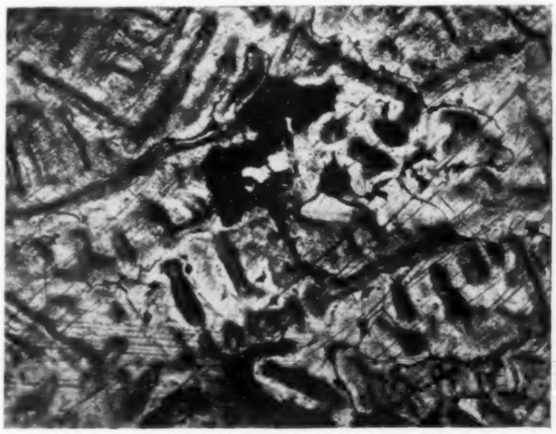

Fig. 1.—Photomicrograph showing interdendritic shrinkage cavities in bronze due to effects of gas absorption or inadequate feeding.

from Admiralty gunmetal, and these are increased to useful limits by suitable heat-treatment. So far as the production of castings is concerned, this material presents no serious difficulties, and the practice common to the ordinary bronze alloys can be employed quite satisfactorily.

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Corrosion-Resistant Materials and Soap-Making Plant

CORROSION-RESISTANT materials are of vital importance in the soapmaking and allied industries, and much of the equipment calls for the use of fairly heavy plates. The equipment in such plants is large, and the economic application of material has been made possible by the adoption of stainless steels and of steel clad with nickel, Inconel, and other materials with outstanding corrosion-resisting properties.

The saponification process in soapmaking involves reaction between alkali and fatty oils or glycerides, fatty acids, or a mixture of both. The fatty acids may be either of animal or vegetable origin, occurring as complex fatty oils—generally the glycerides of organic fatty acids. In producing fatty acids, the first essential is to break down the glycerides into their glycerol and fatty acid constituents, the hydrolitic process employed being known as splitting. This process is carried out at high temperature, and there is now a trend towards the use of autoclave splitting at higher temperatures and pressures than formerly. Tests have been carried out to determine the degree of corrosion on materials suited for the processing of fatty acids, oils, and soaps.* The results were separated into two classifications—the processing of fatty acids and the manufacture of soap,—and provide a useful guide to the selection of suitable materials for the equipment of soapmaking and fatty acid treating plant.

A pertinent point noted was that in some equipment obsolescence might be a more significant factor than actual corrosion rate; thus when obsolescence is likely to determine the life of any piece of equipment, it may be preferable to specify the least costly material, and there is the very important factor that, even though the corrosion rate of one material be higher than another, that material might be more suitable for some purposes on account of the fact that the products of corrosion may be less harmful to the material being processed. It is an involved question, but extensive tests have clarified the position, assisting the designer in his choice of material.

Oils, fats, fatty acids, and caustic alkalis are stored in tanks made of corrosion-resisting materials; nickel is highly resistant to corrosion by sodium hydroxide and is preferred for the handling of caustic; nickel evaporators are widely used for the manufacture of sodium and potassium hydroxides; and "Ni-Resist" is used for equipment such as pumps and heavy castings. In soapmaking the product needs protection against discolouration; soap-boiling kettles are made from nickel-clad steel, steam jets or coils being of nickel or Monel. Nickel, Inconel, Monel, and Ni-Resist have been found to be strongly resistant to corrosion by the acid and caustic treatment of spent lye; nickel is used for pipes and evaporator tubes, and nickel-clad steel for tanks and evaporator bodies; nickel-clad steel is also used for brine tanks in some plants where the salt is added to soap kettles as a concentrated brine solution, and pure nickel tubing is adopted in brine pumping systems.

Monel, nickel, and nickel-clad steel have been used successfully for such details of soapmaking and acid-treating plant as crutchers, cutters, frames, mixers, dies, pipes, wrapping tables, and plodders, and it is interesting to note that at least one manufacturer found satisfaction by using cold-rolled, three-quarter hard Inconel strip running against stainless steel and chromium-plated rolls for the doctor blades on drying or chipping rolls.

In some processes ordinary steel would apparently be adequate for corrosion resistance, but the necessity for avoiding iron contamination of the contents makes it advisable to use a nickel-clad steel. This applies, for example, in the separation following the fat-splitting process, and involving glycerol storage and bleaching by the use of activated carbon.

The tests also showed that even small quantities of certain alloying elements have a major effect in improving the resistance of cast iron to fatty acid corrosion. For example, a 3% nickel addition, with or without a small inclusion of chromium, provides approximately twice the corrosion resistance of plain cast iron, and these low-alloyed cast irons do not suffer graphitic corrosion to the same extent as plain iron. It is stated that probably the duration of cast iron used in fatty acid distillation plant is largely determined by the protection afforded by graphite layers when they have become sufficiently impervious to prevent progressive attack. Ni-Resist was quoted as specially suitable in this direction, plus the advantage of availability in cast shapes at relatively low cost.

It is evident that the choice of materials is also influenced by such properties as amenability to fabrication and mechanical qualities.

* *Ind. Eng. Chem.* 30. 12. 1350.

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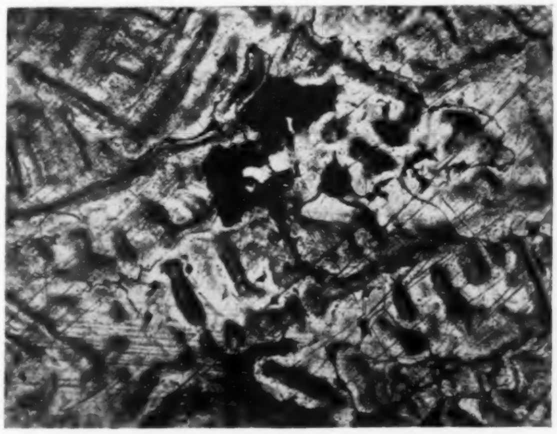

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ferrous founder has to produce—the tensile test-bar. What is the best method of moulding? The particular type of alloy being handled will, of course, have a considerable bearing upon this matter, but so far as the bronzes are concerned, there is at the present time still considerable scope for improvement.

In 1936[5] the Non-Ferrous Sub-Committee of the Technical Committee of the Institute of British Foundrymen published a report covering "Recommendations for Two Leaded Gunmetals," advising the method of preparing test-bars. Although the method was a step in the right direction, it was found to be open to two objections—the tendency of the finished machined test-piece to break at the shoulder when being pulled at loads below those normal to the material, due to a drop in density and a difference in mechanical properties between the metal at the shoulder and that in the centre of the bar, and the fact that failure invariably occurs at the end of the bar farthest from the ingate, at the riser end where the metal is coldest, the difference becoming more pronounced as the length of the test-bar increases. The variation in properties seems to be due to slight interdendritic shrinkage caused by unequal feeding action brought about by the difference in temperature between the metal in the runner and that in the riser.

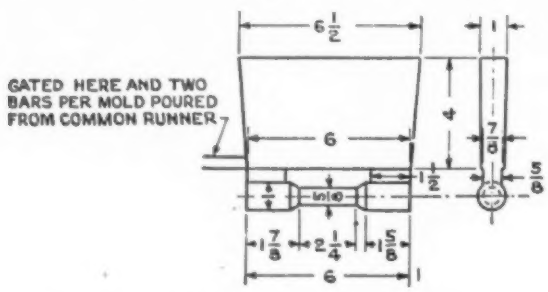


Fig. 4.—One of the recommended methods of test-bar preparation put forward by U.S.A. Federal Government.

To obtain maximum density those parts of a casting last to solidify should be supplied with hotter metal from a riser, so that positive feeding can be assured. This type of bar is unsuitable for use with the 5% nickel bronzes in the heat-treated condition as it gives low elongation values due to the presence of that interdendritic shrinkage. The obvious remedy is to reverse the thermal difference by pouring both ends of the test-piece at the same time by adopting the method illustrated in Fig. 2.

From the theoretical point of view, one cannot understand why non-ferrous castings should so often be poured through large runners of such size that it is impossible to keep the runner basin full; at the same time, it seems illogical to continue the use of a method which readily permits slag, etc. to enter the mould with the metal stream when more efficient alternatives are available. The use of choke gates with adequate feeding risers should, on the whole, permit better non-ferrous castings to be obtained, and they are essential for the handling of special alloys (such as those containing nickel) which form surface oxide films when molten, or when slags or fluxes are employed during the melting operation.

Trouble arising from the presence of defects at the meeting-place of the two metal streams in the middle of the bar has not been experienced in actual practice, even when relatively high melting point metals such as Monel have been used. It is advisable to vent the top part of the mould thoroughly, or place a "whistler" at the middle of the bar to release air. These "whistlers" should be observed in Fig. 3, which illustrates the Eash pattern that has been used in the United States, giving excellent results with the heat-treatable 5% nickel bronzes, nickel silver and Monel. This design will give consistent results when used for ordinary gunmetal and bronze. Personal observation shows that many of the most successful founders producing pressure castings are using similar gating practice to that shown in Fig. 5.

Recommended factors for obtaining maximum density and freedom from porosity are: pour at a suitable temperature, obtain proper heat and metal distribution in the casting proper, supply hot metal to those heavier sections which should be the last to solidify, employ well-proportioned risers on sections requiring feeding, arrange that the metal in the rises is hotter than in the casting, and adopt choke gates for cleanliness and pouring control.

Incorrect Pouring Temperatnre

The necessity for pouring the majority of bronzes at a certain degree of superheat, determined by the composition of the metal in conjunction with the design and mass of the casting, has been a frequent topic for discussion, but there is one aspect which deserves further consideration—the reason for the rather narrow and critical range of pouring temperatures particularly when handling the copper-tin alloys. The foundryman casting a large number of pressure sections may often find that, towards the end of the pour, a number turn out "leakers," but if the initial temperature at which pouring commences is increased, the trouble is probably transferred to the first castings through "tin sweat." A suitable explanation of the reason for "tin sweat" is not easily defined.

It has been suggested that this liquation of the metal is caused by contraction of the outer skin of the metal, or that it is due to the evolution of dissolved gases. The latter appears the more likely. It is reasonable to assume that if steps are taken to prevent gas absorption, or to degasify before casting, the effect of pouring temperature will be less critical. The permissible practical range could be extended by the use of slightly higher temperatures without serious reduction in casting density or mechanical properties, and without fear of the occurrence of liquation or "tin sweat." Lepp[6] has shown that the mechanical properties of nearly all the standard non-ferrous alloys can be improved considerably by degasification, as shown in Table II.

TABLE II.

Composition.					Tensile Strength Tons/sq. in.	Elongation per cent.	Brinell Hardness.
Cu.	Sn.	Zn.	Pb.	P.			
88	10	2	0·5	—	20·3–23·5	40–70	70–90
85	8–9	4–6	1–2	—	19·0–21·6	35–62	70–75
85	5	5	5	—	17·8–19·0	35–47	60–65
90	10	—	—	<0·1	20·3–23·5	40–65	70–80
87	13	—	—	do.	20·3–22·9	10–20	90–100

Controlled cooling by the use of chills is useful, but is impracticable in many cases. The effect of alloy additions may be very good. Pilling and Kihlgren[7] have found that small additions of nickel appear to have a real effect in reducing grain size. In the usual range of pouring temperatures the refinement averages about 50% reduction in grain diameter for 1·5% nickel or less, counteracting to some extent the effects of slightly increased pouring temperatures on grain size, and these small additions of nickel also have the effect of imparting fluidity to bronze and gunmetal, whilst yet another effect is to promote solidity.

The latest high heat conductivity crucibles are undoubtedly of great advantage for rapid melting, but they permit the metal to cool much more rapidly during the casting operation, and there is difficulty in maintaining a specific range of pouring temperatures. There is need for a refractory lagging for the crucible, or possibly the use of a dual crucible with high heat conductivity for the inner crucible, and the lowest possible heat conductivity for the outer member.

5 Inst. British Foundrymen. "Recommendations for Two Leaded Gunmetals." Proc. Inst. Brit. Foundrymen, 1935–36 xxix, 349–359.

6 H. Lepp. "Mechanical Properties of Some Tin Bronzes." Tech. Publ. International Tin Research and Development Council, Series D., No. 3.

7 N. B. Pilling, T. E. Kihlgren. "Casting Properties of Nickel Bronzes," Trans. Amer. Foundrymen's Assocn. 1932, iii, 289–305.

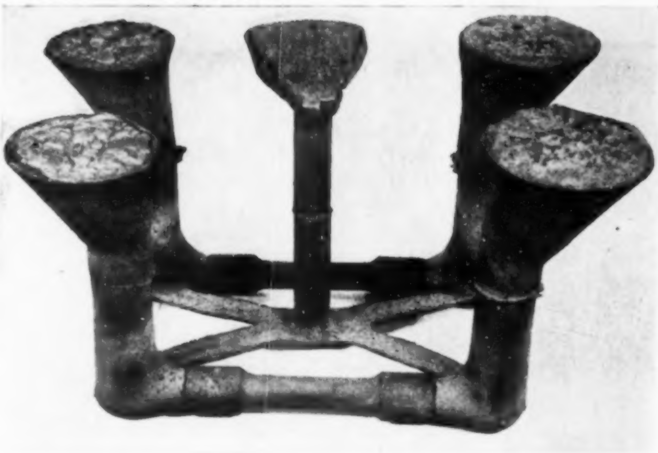


Fig. 2.—Modified method of running I.B.F. bar to ensure even feeding action and more consistent results.

Fig. 5.—Successful methods of running test-bars can be applied to castings, as shown in this valve body in bronze containing 5% Ni, 5% Sn, 2% Zn, bal. Cu. and tested to 10,000 lb. per sq. in. without leakage.

Gas Absorption due to Improper Melting and Deoxidation Methods

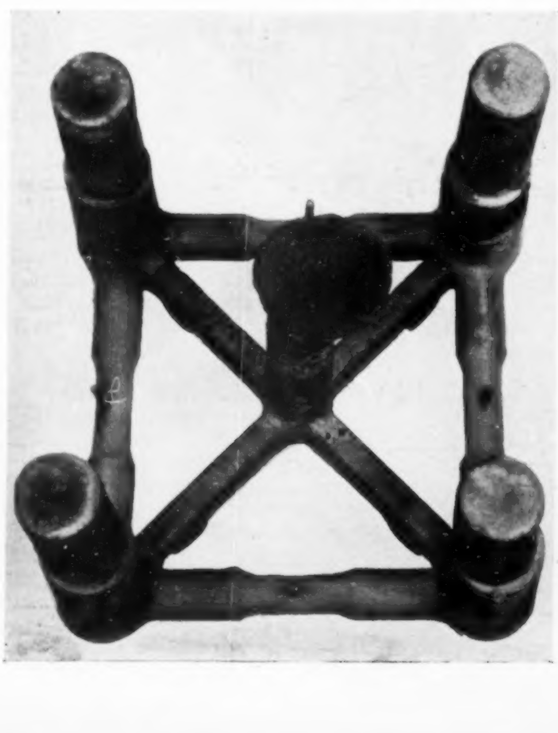
The importance of the effect of gases on cast metals should be realised by all foundrymen, and the first essential is to ensure an oxidising atmosphere during melting ; the ease with which this can be maintained depending upon the melting furnace available.

The premier furnace for non-ferrous melting is undoubtedly the electric induction furnace, preferably the high-frequency type, which enables the metal to be melted rapidly in contact with air containing 20% oxygen, with a natural circulation in the molten metal created by the induced current, effectively distributing the oxygen, and harmful gaseous products of combustion are absent. For many alloys handled in the brass foundry 20% oxygen has not been found to be excessively oxidising, and it has been noted that there is no difficulty in obtaining carbon absorption when melting nickel in a high-frequency furnace.

In the arc-type furnace current and electrode consumption should be so controlled as to prevent neutral or reducing conditions arising and excessive overheating of the metal avoided. There seems no reason why such furnaces should not be operated with oxidising slags and they can be lined readily with basic material. The best of the refining slags have a severe cutting action on graphite crucibles and acid refractories.

Fig. 3.—Eash pattern test-bar as employed in the U.S.A., and found to give excellent results with 5% nickel bronze, nickel silver and monel.

(Courtesy of Phosphor Bronze Co. Ltd.)



But the average founder in this country looks to either the oil or forced-draught coke-fired crucible furnace for his molten metal requirements. Oil firing probably has the greater advantage, providing rapid melting and reasonable control of oxidising conditions. If it has an open top the presence of oxygen can be detected by the colour of the exhaust, and if the exhaust flue is connected to a stack the combustion gases should be analysed to determine the oxygen content at various settings of the oil and blast valves, maintaining a setting of, say, 0·2% to 0·8% oxygen. A chemist or metallurgist should be employed. Positive oxidising conditions can, however, be obtained without analysis by the use of slags or fluxes which evolve oxygen when heated, and this is of particular importance in connection with natural-draught coke-fired furnaces which in many cases operate with a reducing atmosphere. Manganese dioxide, black cupric oxide, red cuprous oxide, nickel oxide, and barium peroxide can all be employed. Lepps' degasification process[8], which is probably the most effective, uses a balanced mixture of oxides in conjunction with other fluxing materials such as soda ash or barium carbonate. The addition can be made with the charge before melting or arranged after the metal is melted and prior to the addition of deoxidisers.

An addition of 1-2% manganese-dioxide or cupric oxide is usually ample to cover melting times up to two hours. For longer periods, add half the flux initially and the balance about midway through the melting period. The second method is preferably recommended to assure complete degasification of alloys presumably already melted under oxidising conditions. Cuprous oxide is usually most favoured and is added in an amount around 0·2% by weight of the charge, for virgin metal heats, and reduced to 0·1% for the more usual foundry heats embodying up to 50% remelt. Cupric oxide can also be used, particularly as it has a greater oxidising action and a greater affinity for hydrogen. The main characteristics

8 Brit. Pat. 429,440. See also H. Lepp, "Deoxidation and Degasification of Metals. Developments in Refining Methods." Metal Ind. (Lond.), 1935, xlvii, 315-18, 341-345.

TABLE III.
PROPERTIES OF FLUX MATERIALS.

Material.	Chemical Formula.	Colour.	Approx. Melting Point °C.	Oxygen Dissociation on Heating °C.	Remarks.
Cupric Oxide	CuO	Black	1,150	1,100	Strong affinity for hydrogen and evolves oxygen at yellow heat.
Cuprous Oxide	Cu_2O	Red	1,240	nil	Reduced by hydrogen to metallic copper. Does not evolve oxygen when heated.
Manganese-Dioxide .. (Manganese ore)	MnO_2	Black	1,300	700 to 800	Evolves oxygen above a red heat.
Barium-peroxide	BaO_2	White	2,000	450 to 700	Evolves oxygen below a red heat.
Barium-carbonate ...	$BaCO_3$	White	1,400	—	Reduces slag fluidity. Good desulphuriser.
Calcium oxide ...... (lime)	CaO	White	2,250	—	Useful for hardening slag to facilitate skimming.
Sodium carbonate ... (soda ash)	Na_2CO_3	White	850	—	Useful for controlling slag fluidity and fluxing dirt. Tends to reduce sulphur.

of the most useful flux forming constituents are outlined in Table III.

In connection with the 5% nickel bronze the following procedure[4] has been found to work well in oil-fired crucible furnace heats using virgin metals :

1. Melt down copper and nickel using a moderately oxidising flame.
2. When thoroughly melted oxidise heat with 3-oz. cuprous oxide to 100 lb. of metal, stirring in oxide with an iron rod. Hold heat for three to five minutes.
3. Deoxidise melt with 3-oz. of 15% phosphor copper per 100 lb. of metal.
4. Add zinc, followed by tin.
5. Finally, complete deoxidation by a further addition of 4 oz. of phosphor copper per 100 lb. of metal.

Melts treated with copper oxide respond more vigorously to age hardening. Finally, do not use charcoal as a cover, and do not use wet coke.

Future possibilities in connection with heat-treatment of castings should not be overlooked. The improvements obtained in respect of bronzes containing say 5% nickel are most marked, but precautions must be taken to prevent dendritic shrinkage and porosity ; whilst the presence of as little as 0·05–0·10% lead has been shown by Kihlgren[4] to retard or completely inhibit response to heat-treatment, and small amounts of silicon tend to prevent age hardening.

In the initial investigation of the 5% nickel bronze it was found that the homogeneising period at 760° C. could be reduced from 10 to two hours without sacrifice in the optimum properties, or that it could be omitted entirely and the castings aged direct from the sand. Whilst the omission did not develop maximum properties, the improvements were such as to constitute a distinct advance in the practical metallurgy of the bronzes.

Welding Fissures in Chromium-Molybdenum Steels

THE purpose of this investigation by Peter Bardenheuer and Werner Bottenberg* was to find out the connection between the method of steel production and the tendency to form welding fissures. In rare cases these fissures occur in the welded seam. They may be the result of :—

1. Stresses caused by the difference of heat ng at various points.
2. Failures of the welding auxiliaries.
3. Mistakes made during the welding.
4. Impurities of the material to be welded.

The tests were made on experimental casts, each of about 440 lb., of different analyses, which were produced partly in arc furnaces—basic casts—and partly in induction furnaces—acid casts. The alloy additions used included Mn, Si, P, S, Cr, and Mo. Four casts were produced in order to investigate the influence of the various alloys—i.e., carbon, phosphorus, sulphur, and aluminium, and ten casts in order to find out the effect of various melting processes—i.e., variation of melting and refining times, of temperature, addition of alloys at various times during the melting process, of the condition of the raw material, etc. The ingots were hot-rolled into plates of 4 mm. thickness (0·18 in.) and, after annealing, cold-rolled into strips of 1 mm. thickness (0·04 in.). The tests included chemical analyses and tensile tests of the steels in the annealed and unannealed state, and bending tests of welded strips ; the fractured pieces were investigated by microscope and X-ray methods.

The results of these investigations may be summarised as follows :—

The tendency of these steels to form welding fissures increases with increasing content of carbon, aluminium, phosphorus, and especially sulphur, but this influence is less important than that of variation of the melting process. In order to produce steels with a low tendency of welding fissures, it is most important to boil the melted material for a sufficiently long time and vigorously. The influence of the charge, of the casting temperature, and of the cold-rolling, could not be stated.

The fact that the welding fissures appear in the range of the transformation temperature, leads to the conclusion that internal stresses due to the consecutive pearlite and martensite transformation, as well as material and temperature stresses, had a share in the formation of the fissures.

The difference in the behaviour of the materials tested can be explained as a consequence of the influence of hydrogen. As the hydrogen absorbed during the welding process only produces stresses when the material contains a certain amount of non-metallic inclusions, the content of oxides has to be kept as low as possible by correct melting procedure. The lower the content of oxides in the steel, the more admixtures of phosphorus and sulphur can be admitted. This is favourable, as the content of these elements cannot always be lowered to a desirable content by the melting procedure. The coarser the grain, the easier are welding fissures caused by the hydrogen.

The hardness of the welds depends only on the quality of the steel and not on the tendency to form welding fissures. In pursuance of these investigations, experiments were made with welding wires suitable for oxy-acetylene welding of steels, in order to determine the tendency to welding fissures of the resulting products. Eight different materials, some without chromium and molybdenum, but with increasing nickel content, others with nickel, chromium and molybdenum, and having the tendency to fissure formation, were tested, and the majority were welded by means of 14 welding wires of different analyses.

An improvement of the properties of the welded materials at the welded seam could be observed generally, and it could be stated that even material with a high fissure formation tendency could be welded faultlessly, if welding wires of a certain nickel content were applied. The resulting properties of tensile strength and elongation were sufficient for practical purposes. The metallurgical behaviour of these welding wires and the formation of the welded seams were good.

* Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Vol. XX, No. 7.

Nickel Steels in Machine Tools

In gear hobbers, thread millers and similar machine tools, heat-treated nickel-alloy steels are usually specified for vital parts to obtain a maximum combination of strength and wear resistance, and hence long life. Parts of these machines which are generally forged from alloy steels containing nickel include the main driving shaft, the cutter head driving shaft and gears, spindles, the hob shaft, bevel gears in the carriage, transmission gears, clutch shaft, and the headstock bevel gears and studs.

Industrial Management and Production Control

Part VI.—The Time Study Man and His Task*

By F. L. Meyenberg

The article shows how the work of the time study man has changed since the days of Fred W. Taylor, how it has developed into research work on all problems related to the working of machines and the labour of men, and which qualities are therefore expected from the man who has to do this job. Further, it points out that important work which still lies before him—i.e., the classification and evaluation of work with all methods, which not only technical science, but also current physiological and psychological knowledge, will, it is to be hoped, develop in future.

LOOKING back to-day on the development which the conception of time study in industry has passed through in the thirty or forty years since Fred W. Taylor published his fundamental considerations, we realise how much our perception of this problem has changed since those days. At that time everything seemed to be so simple that perhaps few people understood why this method should be treated in such thoroughness. Perhaps it was only the simple language used by that important man which brought about this wrong impression; for it is scarcely probable that he himself did not anticipate to a certain extent the intricacy of the method whose systematic use he recommended to the production engineer in such convincing words. In the meantime, we have learned very much, particularly by the mistakes we have made in carrying out time studies and applying their results. In this connection the fact may be mentioned, that we have discarded consideration of a human being, when the object of a time study, as an analogy to a mechanism, but consider it as a totality, an organism composed by body, brain and spirit in a manner which is following laws very often still unexplored, perhaps even inscrutable. In any case, in spite of the many publications on this problem—one may even say the extensive library—which exist, we have now attained a point of view which demands great care when applying time study methods, a care rarely enough realised by an outsider, and sometimes even not used by a specialist.

The Time Study Man

In these circumstances it is only natural that the demands on the man, whose task it is to carry out such investigations, have changed considerably. We were accustomed to look at him as a person who had to consider carefully the processes and operations in the workshops, to improve them according to the best of his knowledge and experience, to determine the times with more or less accuracy according to the nature of the observed job, and then to draw all possible conclusions from these observations. Certainly a very important task, and one that should not be disregarded even if the greater task, which I want to explain now, has to be attempted; for that first task can and must be the basis of the further development.

By making time studies—or, let us say, work and time studies in this sequence,—for the work study is the more important part of the job—the observer has to act on the basis of *personality*. Besides his mental qualities, based on professional knowledge and experience, which he has to use particularly during the considerations outlined above, a series of qualities of character are necessary, which enable him not only to know how he himself would do the work, but also to feel consciously the very nature of the job, and how another, a personality as he himself, but different from him in thinking and feeling, would look at the work and would like to do it according to his particular mentality. There is no question that this is a demand not easily fulfilled; but it is equally certain that where this quality of, should we say, putting himself outside his own person in the position of another, is lacking, full success, obtainable from research work by time studies, will never result. We must definitely abandon the point of view that workmen are interchangeable like pieces of a machine in mass production; that besides all the similarity which may be found under human beings, at last everybody is an individuality, and that we will do irretrievable damage not only to the single person, but also to the work he has to deal with, if we extort from him a manner of work which is distasteful to him.

The Personality of the Time Study Man

Now what do we mean by our statement that the time-study man should act as a personality? Every psychologist will agree that it is extremely difficult, if not impossible, to give a correct definition throughout of this term, and therefore it seems better not to try to do so. Some individual properties may be mentioned which have a special importance in this case, but it must be pointed out, that they alone, taking each individually and even all of them together, do not make a real personality, if the owner of these qualities does not understand, consciously and more often unconsciously, how to unite them to a harmonious whole.

Those qualities may be, for the purpose of this consideration, divided into faculties, impulses, and temperament.

Faculties

1. General technical talents must be developed especially in such a manner that relations between cause and effect, purpose and means, are quickly comprehended; that motions, processes and production methods are intuitively conceived. Independence from any "scheme," originality of opinion, a certain distance from the routine of the shop, that quality which is expressed in the adage, "The onlooker sees most of the game," are important for the time-study man. Lively interest in new ideas must prevail over a tendency of keeping to the traditional, carefully balancing, of course, one against the other.

2. The time-study man should have the gift of observation—not only to see how the work is done, but why it is done in just that manner, and, moreover, why it is not done in another, obviously easier, better, quicker manner. Now here we have to stop; is there such a thing as absolute truth in judging the work of another person? Is it not possible that what is easier for the one, the observer, is more difficult for the other, the observed? And if so, is that not only temporarily the case? Cannot correct training bring the observed to do the job in the manner indicated by the observer really better than before? Or will this training, if driven too far, perhaps damage his individuality

*This article is partly based on publications of Professor Dr. E. Bramesfeld, of Darmstadt (Germany) in "Machinenbau," No. 15/16, August, 1938, and "Technik und Wirtschaft," No. 7, July, 1938.

and destroy valuable qualities such as his interest in the job, willingness, pleasure in work, etc.? So many questions, so many answers. Only those who have the faculty of observing the working men as individuals can give the right answers, or at least the best ones.

3. Further, that general intelligence is necessary which, assisted by a good memory, is able to distinguish between the essential and the non-essential, to find out the fundamental factors, and to explain them to other people, not only in logical words, but more intuitively, adapted to the understanding of those men by drawing sketches; or, better still, by showing how to do the job in the time suggested. This is perhaps one of the most important, but also one of the most difficult points; for the observer, even if he has been a workman himself, may be out of training for a considerable time, and may have lost to a certain extent the ease of working; but there is no better means of gaining the confidence of the man than this way if it is carried out in the right manner—not as a presumptuous preceptor, but as an experienced friend and helper. Age in this case is of less importance than is generally assumed; for it may easily be possible that the younger man is more experienced than the older, if the former has a higher faculty to learn from that which he has seen and done than the latter.

Impulses

1. The time-study man must possess activity and tenacity without being stubborn. Personalities of the hesitating type who are easily afraid of difficulties which may come their way are perhaps useful in other positions, but must not be taken as time-study men.

2. On the contrary, a certain kind of courage is necessary in grasping a task, the development of which may be wholly uncertain; the will to succeed is often the best help to a good result; readiness to take decisions and responsibility for the consequences should be backed up and strengthened by his superior as long as they remain within reasonable limits, even if an occasional failure results from these very qualities. "The man who has never made a mistake, has never made anything."

3. What is most important, however, is perhaps an unfailing honesty. The time-study man is the born mediator between the seemingly opposite interests which only too often come up against each other in modern workshops; he can fulfil this difficult task only if he has a clear conscience, if he makes his observations with an accuracy as high as permissible under given circumstances—even then certain errors will always creep in as being in the nature of his work—and particularly if he starts his job without preconceived opinion.

Temperament

1. What has already been said under "Faculties" and "Impulses" gives a guide to the demands one has to make on the temperament of the time-study man. He should be neither a choleric nor a phlegmatic person, his should be a "considerate vivacity" only seemingly a *contradictio in adjecto*; for persons to whom this description applies are not so rare as one would at first imagine.

2. Further, he must be socially minded. Too reticent people are often considered arrogant, and it is difficult, if not impossible, for them to come into that contact with the men which is so necessary in producing the confidence we have previously discussed.

Conclusions from these Considerations

1. Looking back on the demands we have enumerated, it is only natural that the question arises—is it possible to find in the circle of persons who apply for the position of time-study men enough personalities to fulfil these demands? The answer is that each description of this kind, elaborating in a necessarily theoretical manner what we are looking for, gives an ideal which rarely or never can be found in practice. One or other of the enumerated qualities will be more or less developed or perhaps missing completely; we have to be satisfied with the men as they are, and cannot change them to what they ought to be. Comparing them, however, with the ideal we have built up, we know their weak points and can watch them better in their work before any major inconvenience arises from one of their weaknesses.

2. But another conclusion seems to be at least equally important, which can be drawn from our considerations. As explained in the beginning, the aspect of the job of the time-study man has changed; and with that also the person has changed who has to do the job. Higher demands are put forward; the time study is put into the background; it is no longer the work itself; it is more and more becoming the means to the proper purpose, which is the study of the work and the management of labour relations in so far as they pass on in the workshops themselves in connection with the work. One consequence which should be drawn from this is that the man who has to do this job should have another name, for the old one—time-study man—is certainly misleading. Sometimes one has called him "efficiency engineer." That that is an improvement there is no question, but it is doubtful whether it is the best name. At the moment I leave this open for further discussion, for I want to draw the attention to another problem which, I believe, will be of great importance for future development. In order to make this clear, I must consider the task of the time-study man in greater detail.

The Task

The time-study man—we will for the present continue to give him this name—may be defined briefly as one who has to make work and time studies and to collect statistical data in order to elaborate basic facts and figures for the layout of new plants, the rebuilding of old ones, the planning and progressing of production, the improvement of production methods and business organisation, for the fixing of fair wages, for comparing the economical effect of various methods of working; in a word, he has to take care of the economics of the works by special investigations—organisation studies, production studies, costing studies, psychological studies—for which other members of the staff, occupied by daily routine work, will not find the necessary time and concentration for reflection. That is explained and detailed so often in literature that it is superfluous to repeat it; the reader may find it easily in other publications if he wishes.

Here I want to draw attention to a problem which is mostly considered out of the scope of the time-study man, if considered at all. Nay, it is even expressly pointed out that he must keep away from it. I refer to the transition from time to money—mentioned already in the fourth of these articles—when building up a system of payment by results, especially piecework wages. It may be called to mind that piecework wages are formed by multiplying the carefully determined time of a special job by an hourly rate, mostly fixed by agreement between the organisations of employers and employees. In declaring that the work of the time-study man ends with the determination of the time, it is assumed that the hourly rate belonging to the kind of work in question is definitely fixed in those agreements, so that it is merely a matter of routine to carry out the multiplication, and scarcely any consideration is necessary, especially not one based on technical knowledge and experience. I know that that is the usual situation at present, but the question may be asked whether this view is right, and the following considerations will show it is not the case. I know that they will be purely theoretical for the time being, but this I am sure will change some day, because the facts will be stronger than custom; and it seems to be worth while to be prepared for the new task, which has then to be tackled. As a matter of fact, the difficulties connected with the problem, with which we shall deal here, are often enough already obvious in practice at present, and one is in the habit of overcoming them in a fairly haphazard way, because basic

investigations are not available for systematic analysis. In order to explain what difficulties are meant, a very simple and well-known example may be quoted :—* "Assume three different jobs done on three different lathes, each occupying exactly the same time, say, 30 mins. One man can do the first with a simple lathe ; special care is perhaps necessary for the second, for which a very small tolerance of inaccuracy is prescribed to suit the requirement of fitting it into another part, or for some other reason ; the third needs intimate knowledge of a special apparatus on the lathe and of its handling. In these circumstances it would be absurd to say, either that the economic value of the three jobs was $30 + 30 + 30 = 90$ mins., or that the three jobs were of equal value.

Possibly the second man's work could be judged to be worth 25% more than the first man's, and the third man's work perhaps even 50% more, so that the calculation would be $30 + (1{\cdot}25 \times 30) + (1{\cdot}5 \times 30) = 112{\cdot}5$ value units, and some such judgment is used in fixing the payment of the men. If we pay the first workman a wage of 8d., the second will have $1{\cdot}25 \times 8 =$ 10d., and the third $1{\cdot}5 \times 8 =$ 12d. per hour."

We see what has happened here : the agreement must contain under the heading " turner " at least three different hourly rates—8d., 10d., 12d. ; or if there are some more intermediate steps of difficulty, 8d. to 12d., leaving it to the discretion of the calculator, which rate he thinks suitable to the job in question, and only intimate technical knowledge of the job will be a tolerably accurate guide to the choice. But which agreement is built up in such a manner ? And if that may be the case for some special position, as perhaps " turning," it certainly is not true throughout for all possible kinds of work.

Here we have to admit that to put forward such a demand on an agreement means to demand the impossible. For our knowledge of the nature of the work, which alone can be a guide to its evaluation, is still so incomplete that no sufficient answer to the question can be given as to how to build up a real and fair classification of the work done in our industrial workshops. But is that a reason to despair and completely set aside this task ? Certainly not ! What is not possible to-day may be possible in the near or remote future. The course of science has always been, first, to state a problem, then to recognise its difficulties, and, last, to overcome them. So let us try to go as far as present knowledge allows.

*See "The New Management," pp. 16-17, Macdonald and Evans, 1938.

(To be continued.)

Quality of Steel in Relation to Hot-Working Properties

By H. Alexander Dickie, D.Sc., Ph.D.

Many factors are involved in the fabrication of steel, of which its hot-working properties provide one of the most important. The steel manufacturer is often blamed for the absence of quality which has actually been removed during the subsequent heating and working. In a paper before a recent meeting of the Midland Metallurgical Societies Dr. Dickie concerned himself more particularly with the quality of steel in relation to the hot-working properties, and his views are summarised in this article.

THE performance of a steel during hot-working and the merit of the resulting product depend on the inherent quality of the steel itself, and on the condition imposed on the steel during heating and working. Composition is of great importance, and must be related to the properties required in the final product as well as to the methods of production. As far as plain carbon steel is concerned, carbon has a greater effect than the other common elements on the malleability at high temperatures. The effect of carbon is two-fold : as it decreases, the steel becomes softer and more malleable at any given temperature, whilst at the same time it becomes possible to heat to higher temperatures and so take advantage of the increase of softness or malleability with temperature.

At high forging temperatures the stiffness of a steel varies almost linearly with temperature, but this is not true of all temperatures. There is a discontinuous change at the critical points which leads to the steel being more plastic when the temperature is within the critical range than when the temperature is either lower or slightly higher. The greater strength of the gamma-iron condition above the critical point is, of course, the basis of the high temperature strength of modern austenitic steels in which the allotropic change is suppressed by alloy additions. These steels are much stronger at high service temperatures of about 500° to 900° C. than are ferritic steels. There is another discontinuous change at lower temperatures, where the steel is appreciably stiffer at about 200° C. than at higher temperatures, or at atmospheric temperature, but this is of no interest in connection with normal hot-working.

Effect of Manufacturing Process

Steels made by different processes may show interesting and useful differences in malleability at high temperatures. This is shown by the increased output of a typical strip mill when rolling basic Bessemer mild steel as against open-hearth mild steel. Similarly, basic Bessemer steel will roll to a thinner section on a particular roll setting. This makes it possible to roll strip to, say, one gauge lighter than the accepted rolling mill minimum, based on open-hearth steel practice. The greater malleability of basic Bessemer steel is explained by its low content of elements which interfere with free flow of the iron base—for example, carbon and silicon and minor impurities, such as copper, nickel and tin. Impurities like these are present in open-hearth steel, sometimes in quite large amounts, and arise from the use of mixed scrap, which is essential to the economy of the open-hearth process, but which is not used in the basic Bessemer process.

Some of the elements in ordinary steel and in low alloy steels have little effect on the malleability or stiffness at high temperatures, but may have other effects during hot-rolling, or as regards the finished product. In the former class are elements which produce, by absence or presence, a type of brittleness or hot-shortness. In ingot iron, in a range of temperature which appears to extend for about 200° or 300° C. above the highest critical point, there is hot-shortness which is affected in ordinary steels by the manganese, sulphur, and oxygen contents. It appears, however, that oxygen occurring in the amounts usual in commercial steel is not of real importance, and that the provision of an adequate ratio of manganese to sulphur is quite sufficient to ensure freedom from hot-shortness. A ratio of five should be more than ample for practical purposes, but it must be noted that if the manganese in mild steels falls below about 0·20% there will be a danger of trouble regardless of the sulphur content. It appears also that steels worked immediately after solidification require a higher manganese-sulphur ratio to ensure freedom from hot-shortness.

Type of Steel and Uniformity

Type of steel and uniformity are of as great, or even greater, importance than composition, and there are many current misconceptions in regard to these factors. Experience has shown that rimming steel is, in fact, superior to killed steel in many respects. Rimming steels give a superior surface, owing to their purity and self-welding properties, especially when made from virgin sources as in the case of Bessemer steel. It is also as good as, and in some cases superior to, killed steel where the interior of the steel is opened out during the manufacture of hollow bodies.

Rimming steel has also advantages in the uniformity of distribution of non-metallic particles. This depends largely on the fact that rimming steel is relatively free from deoxidation products, and, in particular, silicates, which may form objectionable aggregates either in the surface layers or at certain parts of the interior, owing to their coalescing power during pouring and solidification. Intermediate forms of steel between killed and rimming are also available, and in some cases have definite advantages over these common forms. The welding quality of rimming steels should not be overlooked, particularly in the case of low carbon basic Bessemer steels. These can be used with great success for processes in which welding is practically instantaneous, and give excellent results where killed steels cannot be made to satisfy manufacturing conditions.

Superior Properties of Products in Hot-worked Condition

There is a tendency in some quarters to attempt to force producers into normalising after hot-forging or rolling, and it is assumed that normalising will produce useful effects and overcome objectionable features present in the rolled or forged products. It is not generally realised, however, that a hot-worked product may have superior properties in the hot-worked condition, and that even the best normalising could do nothing but injure the general properties, whilst in the case of incorrect normalising serious injury may be produced. Admittedly, particular cases may require special consideration, but it happens that many forging or rolling operations are conducted so that a refinement of grain size to a much smaller size than normal is produced. This results in great toughness in the hot-worked product, as can be seen by comparing the impact values of hot-worked pieces with the same pieces normalised. Hot-worked steel, particularly steel with low or medium carbon content, may easily have 50% or even 100% higher impact value in the hot-worked condition. Incorrect normalising may reduce the impact value to only 5% or even less of the best value in the case of mild steels or low alloy steels of low carbon content, which have a considerable temperature gap between the critical points.

It is worth noting that the ductility of carbon steels increases with time after hot-working. This is reflected in the elongation, and to an even greater extent in the reduction of area, which may be nearly doubled by ageing. The greater part of this increase occurs, however, within the first few hours or days after hot-working, and is not likely to be of practical importance except in cases where steel is put into service very quickly after fabrication, or where the steel is over-stressed in the later stages of working.

Effect of Copper on Hot-Working Properties of a Steel

Attention has been drawn to an increasing extent in recent years to steels containing copper. This element has been used in small percentages for many years for increasing the resistance to atmospheric corrosion of mild steel, but still greater amounts are useful for increasing the general strength properties, including yield-point, and for making use of precipitation hardening effects, which can be brought about by simple heat-treatment of "as-rolled" products. Copper is, of course, attractive as an alloy addition because of its low price when compared with most other alloy elements available.

There are many disadvantages, however, in making use of copper as an alloy element. In steel-making and hot-working practice these are connected with the same underlying reactions as are regarded as of value when heat-treating the final product, and depend upon the limited solubility of copper in iron. Copper is the only element among those commonly available which has such a limited solubility. Red-shortness is a feature of copper-bearing steels when the copper is present beyond a certain amount. This amount has been variously put at 2% or 4%, but in actual fact steels with 1% copper may, under certain circumstances, give serious trouble both at the ingot stage and during hot-rolling. The trouble referred to is a disintegration of the steel, either confined to the surface layers or deep-seated in the steel, and is distinct from the surface cracking which may arise after oxidation in steels containing as little copper as 0·20%. The latter type of fault is of interest to those engaged in hot-working and arises again from the limited solubility of copper in iron. If the temperature is above the melting point of copper, the latter penetrates the grain boundaries of the steel and causes disintegration of the surface when the steel is deformed by hot or cold work. Current theory is that this effect can be avoided, or at least minimised, by addition to the steel of nickel to the extent of about half the copper content.

The only other element of value in this way is said to be cobalt, but it is apparently not so effective. No doubt these elements produce some effect in the particular cases to which they are applied, but it would be a mistake to extend this theory to cover all cases of surface cracking. The facts are that surface cracking can occur in a minor degree, but sufficiently objectionable to injure the surface finish in bright drawn or rolled articles even when little or no copper is present in the steel and at temperatures well below the melting point of copper. The main source of trouble in this connection is, in the author's opinion, sulphur or sulphur compounds, present in the furnace atmosphere. An extreme illustration of the powerful effect of sulphur dioxide on a steel is seen when steel is heated in an atmosphere of pure sulphur dioxide at about 1,000° C., when, in the space of a few minutes, a large laboratory sample of steel is reduced completely to cinder. On analysis, this is seen to consist of a mixture of oxide and sulphide.

The nature and type of steel has an effect on surface rooting or cracking, and nickel accentuates the effect, which is contrary to the theory of its beneficial effect in copper steels. Chromium in large quantity greatly minimises the effect, but probably not in quantities below 1%. Carbon acts in the way of a restrainer, presumably because it must be oxidised and diffuse outwards before rooting commences. The minor impurities present in open-hearth steels lead to a greater susceptibility to this trouble than in the case of basic Bessemer rimming steel, which of all mild steels tested is easily the most immune, owing to its purity in minor constituents and the relative purity of the envelope or surface portion of the steel.

Soviet Iron and Steel Industry in 1938

MUCH progress was made by the Soviet Union in 1938 in all sections of industry. During the months of January to October, 1938, the output of large scale industry had increased by 12½%, as compared with the corresponding period in 1937. In 1938 the output of iron and steel in the U.S.S.R. averaged about 100,000 tons a day, and the output of rolled steel was more than 40,000 tons per day. Two blast-furnaces put into operation in the first half of 1938 at the Zaporozhstal and Azovstal plants have a combined annual output of 950,000 tons of pig iron.

The Production of Stable Stainless Steel

A New Development with Great Possibilities

One of the problems associated with stainless steels is that of overcoming intercrystalline corrosion, a phenomenon which is encountered in service when certain types in common use are heated to facilitate fabrication or working. Many efforts have been made to render these alloys stable with varying degrees of success, but tests seem to indicate that a recent development in this direction is an achievement of great importance, since it is claimed that the method produces stable stainless steels.

A RECENT development in the production of stainless steels seems likely to solve the main problem associated with production since their inception—the problems of producing stainless steels without the introduction of complications in melting, fabrication, working, or in service. During recent years several methods have been developed to overcome this difficulty, and varying degrees of success have been achieved, usually at relatively high cost, but by this method recently developed and applied to commercial production is claimed to be a natural and complete solution to the problem which involves no drawbacks in manipulation and use. The Refined Stainless Steel Co., who employ the Air Ministry tests for stainless steels, as a routine test, and the results of tests by independent investigators on steels produced by the new method indicate that it is a development of major importance and one likely to open new fields of usefulness for stainless steel where it has not been possible to employ unstable materials.

There are many types of stainless steel, but those which have found the widest application are the austenitic steels of the chromium-nickel group—those which contain sufficient chromium to provide high resistance to corrosion and enough nickel to render them austenitic at ordinary temperatures. In this group are the 18% Cr—8% Ni, 18% Cr—12% Ni, and 25% Cr—12% Ni, as well as several other types. Of these the 18–8 is undoubtedly in most regular use for combating the problems of corrosion. Early investigations with steels in this range of composition showed that when cooled rapidly from a temperature of about 1,100° C., they consisted entirely of austenite. The development of new and improved compositions in this range has improved their properties, and now they are regarded as the most ductile and tough materials available to the engineer.

Intergranular Corrosion

The value of these austenitic steels was soon apparent; the chemical engineer, in particular, appreciated the advantages they offered, and he quickly developed processes which had not been possible previously owing to lack of material capable of resisting severe corrosion conditions. It was, in fact, confidently thought that these were ideal corrosion resistant steels under all conditions, but while it is recognised that for a number of purposes the 18–8 stainless steels function admirably, failures occur in service in many important applications, particularly when they are required to resist corrosion at elevated temperatures or after fabrication, when they had been heated to facilitate shaping, and in welding. On investigation it was found that the austenitic constituent was partially transformed on heating in the range of 500° to 800° C. and the grain boundary areas became much less resistant to corrosion.

At first this phenomenon was associated with welding, since destructive corrosion was noted in welds, and it was referred to as "weld decay." Later investigation, however, showed that this failure followed any operation involving the heating of any part in the above range, and the phenomenon is now known as "intercrystalline corrosion." It was decided that this condition was due to carbide precipitation at the grain boundaries, which rendered the material subject to intergranular corrosion.

Effect of Carbon Content

It is known that carbon is present in these alloys in relatively small amounts, but its effect on the steels is so great that it can be regarded as a major constituent. On account of their relatively high carbon content, none of the alloys covered by the group referred to are stable unless heated to about 1,100° C. for a suitable length of time with subsequent quenching. The solubility of carbon in these alloys is very small at temperatures below 600°–700° C., and when it does separate from solution it unites with chromium to form a chromium or iron-chromium carbide, and when this carbide is present the alloy is not really stable at ordinary temperature, and at any temperature below 600° C., bending, forming, welding, etc., promotes the formation of ferrite. Thus the behaviour of these austenitic steels containing carbon depends largely on the solubility of carbon in the alloys and the variation of this solubility with temperature.

The phenomena of carbide precipitation in the 18–8 type of steels is wholly analogous with ordinary time-hardening, but contrary to the ordinary form of precipitation, the precipitant—in this case the chromium carbide—is not uniformly distributed in the metal matrix, but with a preferred orientation along the grain boundaries or on slip planes caused by cold deformation of the metal. The latter depending upon phase transformations taking place simultaneously.

The formation of the carbide, which is rich in chromium—about 80 to 90%—reduces the chromium content of the adjacent metal matrix and lowers its resistance to corrosive conditions. It is this result of carbide precipitation and the subsequent deterioration of the metal which has caused considerable anxiety, in industrial practice, especially as the condition is readily induced by cold-working, welding, or by heat-treatment for the removal of stresses or by the cold-working of ordinary commercial qualities. Various methods for overcoming these phenomena have been suggested and investigated with a view to the production of a stable stainless material, as, for instance, the following :—

1. To manufacture a material with a carbon content below the critical solubility line, whereby the carbon would remain in solid solution at all temperatures and under all conditions of treatment or application.
2. To produce alloys containing approximately 30% Ni in addition to 18% chromium.
3. To form carbides of other elements which have a greater affinity for carbon than has chromium.
4. To make a metal matrix that, in itself, would resist corrosion under such circumstances.
5. To produce a metallic matrix which would resist the migration of the carbides along the grain boundaries and their agglomeration at these boundaries.
6. To augment the solubility of the carbides at all temperatures.
7. To make the metal matrix less sensitive to phase transformations.

Investigations on the lines suggested by 4 to 7 have not produced any useful results, and apparently do not seem to indicate prospects of a solution to the problems of intercrystalline corrosion. Many investigators have advocated the higher nickel alloyed types, but considering that a 30%

Ni alloy involves an additional cost of about £40 to £50 per ton in raw materials alone, and that their further working entails considerable difficulties in comparison with the standard alloys, it will be readily appreciated that these alloys have only been produced in relatively small quantities for special purposes.

The production of a material with sufficiently low carbon to obtain full solubility at any temperature has been considered a commercial impossibility, although the reduction of the carbon content down to or under the solid solubility of carbon at ordinary temperatures, or, say, 0·02 to 0·03%, would appear to be the ideal solution. However, the production of stainless steel with such low carbon content has not been considered practically possible, and attention has been directed to the addition of carbide-forming elements in an effort to diminish the effect of intercrystalline corrosion.

Use of Carbon Forming Elements

The carbide-forming elements which have so far been applied are titanium, tantalum, niobium, or columbium, of these titanium and columbium appear to have been given preference. Titanium is generally added in quantities of six to ten times the carbon content from which losses on addition will give a recovery of about 50% obtainable in the metal. The greatest difficulty has been encountered in depositing a weld metal containing titanium, and experience has shown that titanium in the welding rod does not produce weld metal that is immune to intergranular corrosion, because all or most of the titanium present in the rod is oxidised during the welding operation. Any welded structure of this type, therefore, when heated in the critical temperature range for stress relieving, will show carbide precipitation in the weld metal, which it thus rendered susceptible to attack, and disintegration will take place if the condition to which the weld is subjected is sufficiently corrosive, even though the body metal may be immune from attack.

The use of tantalum and columbium apparently show advantages in comparison with titanium, but the cost is considerably higher. For material to be welded, an addition of about ten times the carbon content is generally recommended, while a materially higher nickel content is usually specified in order to obtain a fully austenitic structure. In some instances, titanium is used for the parent metal, which is subsequently welded with rods containing columbium. At the present time stainless steel treated with titanium carries an additional cost of about £25 per ton for usual sheets, yet no guarantee of its immunity from intergranular corrosion or of its stability is given, especially when the material is to be welded. Those in which columbium is used are still more costly.

Low Carbon Content

On reference to the equilibrium diagram of 18–8 stainless steel, it will be noted that the solubility line of carbon as a function of temperature shows complete solubility when the carbon content does not exceed approximately 0·02–0·03%. Working on this principle, Mr. S. Westberg, of the Refined Stainless Steel Co., Ltd., claims to have found a solution, and production of stainless steel on a commercial scale is being carried out by which the carbon content can be kept at these low figures.

It is known that a steel which has been subjected to attack along the grain boundaries as a result of intergranular disintegration may show no visible signs of attack of the material itself, but the metal will have lost its metallic ring, suffered a considerable loss in strength, and, if the material is subjected to bending or other stress, a network of cracks will develop and the grains may even fall apart. One of the most sensitive tests for attacks of this kind, however, is the conductivity test for determining the depth of penetration of intergranular corrosion, and it is interesting to note the relationship between maximum sensibility and the carbon content. The following table shows the penetration of steels with increasing carbon content after heating 100 hours :—

ANALYSIS.

C	Cr	Ni	Cr Ni	Max. intergranular penetration in mils per 100 hours.
0·035	15·5	8·1	23·6	160
0·040	19·2	7·7	26·9	370
0·050	17·4	8·8	26·2	390
0·060	16·3	8·4	24·7	490
0·070	17·5	8·9	26·4	620
0·080	16·5	11·3	27·8	580
0·090	18·1	8·9	27·0	670
0·100	18·6	9·0	27·6	900
0·140	16·5	8·6	25·1	1,450
0·200	17·6	8·6	26·1	1,750

It has already been mentioned that the use of additional elements like titanium and columbium involves complications through losses by oxidation and the cost of steels so treated is relatively high. By comparison, the production of steel with carbon content below the critical limit for carbide precipitation entails no complications. The cogging and rolling of this special low carbon product is better than that of the ordinary types, and such operations as welding, straightening and finishing are carried out with every satisfaction and offer no difficulties. In contrast to materials alloyed with titanium, tantalum, or columbium, with this low carbon steel it is possible to produce welding wire or electrodes which, allowing for a small loss of chromium, will produce a weld having the same low carbon content as the material in sheet or plate or other form.

Produced in the form of low carbon 18–8 material and subsequently rolled into sheets or cold-rolled strip, this steel has been subjected to stability tests to the well-known methods of Hatfield and Krupp, as well as that of the British Air Board, with entirely satisfactory results. The latter tests have been carried out by prolonging them to several times the normal time of 72 hours without any alteration in the behaviour of the material.

Welding Low Carbon Stainless Steel

In the welding of this material, it is of course necessary to employ methods which will prevent the carburisation of the weld metal. With regard to the value of various methods in this respect, it may be noted that :—

1. Welding electrodes for arc welding having a coating free from carbonaceous substances, possessing a suitable surplus of chromium, and having a core of alloy with the carbon content below the critical limit, give a deposit with the same low carbon content, and the weld and parent metals will, chemically speaking, be almost identical in composition. It should be observed that the ordinary electrodes available are too high in carbon content for this purpose, and the weld metal would be carburised if they were used. Thus to make a stable weld the electrode employed must be a stable, low-carbon material.
2. The use of the hydrogen flame with such low carbon material results in a weld of very low carbon, and the extreme heat developed will not deleteriously affect the material in the sheet form, but the cost of this method is still rather high.
3. Autogenous welding is a rather uncertain welding method from a chemical point of view, as the material should preferably be welded with a neutral flame in order to prevent any absorption of carbon. Usually the welder will make use of a slightly reducing flame, and the danger of carburisation is always present. The dependability of the weld, therefore, will depend upon the ability of the welder as well as upon the welding rod. These factors naturally have greater importance when the material to be welded has a very low carbon content.
4. The carbon arc method is being increasingly employed, especially for thin sheets. The carburising action of the carbon arc is dependent upon the length of the arc, the characteristics of the machine and the welding voltage being used. The application of carbon arc on ordinary material and also on this special low carbon material, especially in cases of severe corrosive service, must be said to entail considerable risk.
5. With regard to butt welding, spot welding (resistance welding), etc., what has been referred to with reference to

the behaviour of the material by being heated in the critical temperature range, is of still more importance. When such fabrication methods are desirable, the use of low carbon stable material should be very useful, especially in the welding of aircraft constructions made from cold-rolled strip possessing very high tensile strength.

New Production Method Summarised

Briefly, the advantages claimed for the new production method developed may be expressed as follows :—

1. The steel produced is easily forged or rolled, and behaves extremely well during these operations, and it will show a superior finish after grinding and polishing. Having the same analyses with regard to chromium and nickel, this new material will, with regard to corrosion resistance, compare favourably with best obtainable.

2. The steel is easily weldable by known methods of welding, and it is possible to obtain stable welds by employing methods where a carburisation may be avoided, as by arc welding, hydrogen, and resistance welding.

3. The material may safely be heated in the critical temperature range—for instance, for stress relieving of cold-worked or welded articles.

4. This low carbon material can be marketed at prices in the range of standard stainless materials.

5. It offers an ideal and complete solution to the problem of producing stable stainless materials and does not introduce any complications of any kind, neither in melting, fabrication, working, or in service.

The Manufacture and Use of Cemented Carbide Tools

THE production of cemented carbide tools calls for the presence of two distinct constituents—an intensely hard compound, which will remain essentially stable and infusible at all heat-treatment temperatures, and a soft but tough and ductile metal or alloy with a comparatively low melting point, which will possess such characteristics that it will not react with the former constituent at the heat-treatment temperatures that are employed. The two constituents are prepared as an intimately mixed powder, pressed into a block, then heat-treated at a temperature that causes the softer constituent to melt and bond the harder into a compact mass. A number of elements such as tantalum and titanium are used, but the most generally used are the hard metals containing cobalt and tungsten carbide. Whilst the cold-press method is the more generally adopted, Mr. H. Burden describes both this and the hot-press method in a publication recently issued by the Brown-Firth Research Laboratories ; the hot-press method, however, is not yet reliable and is not used industrially. In the cold-press method, he says the tungsten carbide is first produced by heating a mixture of the primary elements in a reducing atmosphere for 3 or 4 hours at approximately 1,500° C., the resultant carbide being always the mono-carbide, which is then broken down by crushing and is mixed with cobalt in a ball mill.

The very fine powder, with a small proportion of wax or oil, is pressed in hardened steel dies at pressures up to 100 tons per sq. in., forming blocks of suitable size and shape for the production of tool tips. Further toughening is carried out before final shaping, this generally consisting of a semi-sintering operation in which the blocks are heated in a reducing atmosphere, such as hydrogen at temperatures ranging from 800° to 1,000° C. At this stage the blocks can be cut to shape, but will withstand handling ; sharp edges, and definite forms can be obtained by the use of abrasive wheels on special machines, and are then ready for sintering. They are placed in a boat of carbon or other refractory material, and often surrounded by powdered carbon and alumina to prevent decarburisation if the tips are not sintered in vacuo. The temperature employed is between 1,350° and 1,500° C., the period varying from 15 mins. to 2 hours according to the properties required of the alloy. The rates of heating and cooling are controlled, as they give definite characteristics to the product.

The author shows that many variations of the process have been devised to get over some of the inherent difficulties which occur, and to produce products with modified characteristics. For instance, in the manufacture of an alloy containing only 3% cobalt and 97% tungsten carbide, it is extremely difficult to ensure the even distribution of the cobalt. One method that has been proposed to accomplish this is to electro-plate the carbide particles with cobalt metal, whilst another is to add the cobalt in the form of oxide or similar compound, which, after being evenly mixed with the carbide, is reduced to metal by the application of heat in a reducing stream of gas.

If the sintering is carried out rapidly and at low temperature the material is finer grained than if carried out at higher temperature and more slowly, but if the temperature is too low or of too short duration, there is the possibility of incomplete bonding. Cooling also is important. If too slow, small rosettes of precipitated graphite are formed and the tungsten carbide will be precipitated almost entirely from the cobalt. Too rapid cooling prevents graphite formation and tends to retain a higher percentage of tungsten carbide in solution in the cobalt matrix. Generally, those alloys produced by rapid cooling are more rigid and harder, with more resistance to shock than those produced by slow cooling.

Three other metals are used—tantalum carbide, titanium carbide, and molybdenum carbide,—and an important class is that which contains a bulk of tungsten carbide with additions of up to 20% tantalum or titanium. For tool-making the carbide tips are brazed to carbon steel shanks, but the fabrication of reamers, inserted teeth cutters, counter bores, milling cutters, and drills is best left to the makers of the carbide alloys.

The straight tungsten carbide alloys can in all cases be made to withstand more shock than those containing carbides of the other three elements mentioned above. Unless the conditions are very severe, carbide may always be applied successfully on non-ferrous metals. Cutting speeds vary from about 20 ft. per min. on chilled iron to about 600 ft. for light finishing cuts on cast iron, and up to 6,000 ft. on some of the lighter non-ferrous alloys. In one instance, a carbide tool was cutting at a speed of 20 ft. per min. with a feed of $\frac{1}{32}$ in. and a cut of $\frac{1}{16}$ in. Under these conditions a tool with a tip of approximately 35 grms. weight will cut for a total period of 175 hours before being worn out. The wear is high, but before the advent of carbide tools no other tool could be made to cut this material—a 12% manganese steel—at all.

Cutting of mild steel, high carbon and alloy steels is much easier. A tool of the following analysis : Carbon, 6·8% ; iron, 1·0% ; titanium, 7·5% ; cobalt, 6·5% ; and tungsten, 78·2% would machine-drill shanks from bar up to $\frac{13}{16}$ in. diameter at a speed of 3,000 r.p.m., and a feed of 0·009 in., machining 1,700 to 2,000 drills before requiring regrinding. Alloy steel forgings, repetition work on automatic and turret lathes, are successful applications of cemented carbide tools, and their application to tools other than lathe tools does not prevent any great difficulty provided there is adequate rigidity of fixtures and set-ups.

In the drilling of soft ductile materials, high-speed steel is found more satisfactory than carbide drills, and it is only when cutting harder and more abrasive materials that carbide drills show to advantage, such as in the drilling of chilled cast iron and alloy steel shear blades.

The author points out that carbide-tipped tools are being more extensively employed where worn or obsolete machinery is being replaced by machine tools of modern design, possessing the rigidity and robustness of construction essential for their satisfactory use.

Silver-Rich Alloys as Bearing Metals

In large modern aircraft engines, where the materials of construction are stressed to the maximum safe limit, the limitations of present bearing metals have been realised for some time. At present, two alloys are in general use for such purposes, both of which are used as a 0·02 in. lining on a mild steel back. The first is a copper-lead alloy containing 71% copper, 28% lead, 1% silver. This material has excellent bearing properties, and with existing designs no seizures result even in times of extreme overstress, such as during diving. Due, however, to the dendritic structure of the alloy, its strength is low, and it is susceptible to failure by fatigue cracking. The other alloy contains 72% copper, 25% lead, 3% tin, the tin addition causing a change in structure which increases the strength considerably over that of the first alloy. This increase in strength is sufficient to prevent fatigue cracking, but this alloy, either because of the difference in structure or some other effect of the tin, is not so good a bearing as the first one, and in times of overstress may seize. Bearing pressures have therefore to be kept low with either alloy to prevent those two types of failure.

About two years ago, certain manufacturers connected with aircraft engine construction in the United States began experimenting with steel-backed bearings lined with silver of over 99% purity. It was found that there were great possibilities to the silver-bearing, it being strong enough to resist fatigue cracking, and its bearing properties such that it was possible to dive at higher loads and speeds without seizure. At the recent congress of the American Institute of Metallurgical and Mining Engineers, the bearing possibilities of these alloys were discussed in a paper by R. W. Dayton,[1] and the relative frictional properties, as determined on the Amsler wear testing machine compared.

The qualities which are called frictional properties are those that make a metal useable as a bearing, other properties being only desirable adjuncts. In this investigation of silver as a bearing alloy, the decision was made to begin by investigating only the frictional properties of silver and its alloys, for although silver has a fair strength and hardness, a high thermal conductivity which allows of the dissipating of local hot spots, a low modulus of elasticity, which indicates a high ability for elastic accommodation, shows almost no tendency to gall on steel, and has a comparatively low, dry coefficient of friction against steel, none of these properties can be construed as giving any indication that pure silver is a good bearing metal.

The frictional tests were determined on an Amsler machine, in which a steel disc, driven at 420 r.p.m. through a torque dynamometer, is the shaft of the bearing under test, and which rotates in the machined notch of the rigidly held bearing metal specimen, loads of 500 lb. being applied to the bearing by calibrated springs. The steel disc and a portion of the bearing metal specimen being immersed in a bath of motor oil maintained at 120° C. (250° F.). All relative seizure resistance values obtained on this machine are given in terms of a standard alloy, 71% copper, 28% lead, 1% silver, which is regarded as 100% on the arbitrary seizure-pressure scale. An alloy which gives 100% or over should carry the loads at present required by aircraft service without seizure.

The test data obtained are given in Table I. and show that both the Amsler and service tests line the metals up in the same order of seizure resistance.

TABLE I.

Alloy.	Order of Merit in Engine Tests.	Relative Seizure Resistance Values in Amsler Tests. %
Silver Bearings	1	115
Cu 71, Pb 28, Ag 1	2	100
Cu 72, Pb 25, Sn 3	3	75

[1] *Metals and Alloys*, 1938, Vol. 9, No. 12, pp. 323-328.

A large number of tests were made on alloys of silver run against highly polished carburised steel shafts having a Rockwell hardness of 57° C. The results which are given in Table II show that all alloying additions tend to lower the seizure pressure and that extremely pure silver is very desirable.

TABLE II.

Alloy.	Relative Purity.	Relative Seizure Resistance. %
Electrodeposited silver	1	165
Double refined silver, remelted	2	140
Double refined silver, deoxidised with 0·15% Cu–P	3	80

The seizure resistance of silver is also not improved by alloying with any of a long series of elements. All tend to reduce the seizure pressure, some to a much greater degree than others. Lead is the least harmful, and antimony the most harmful. A trace of some elements, such as barium, bismuth, calcium, phosphorus, and antimony is sufficient to spoil the alloy as a bearing, while large quantities of other elements, such as lead, sulphur, tin, zinc, manganese, or cadmium may be present without doing the same harm. The relative harmfulness does not seem to depend on microstructure, on hardness, or on any other known property.

In engine tests it was found that pure silver did not always behave ideally. In general, silver bearings ran at higher loads and speeds, without seizure, than other materials, but at times they seized at comparatively low loads. One particular bearing was found to seize at relatively low loads after running successfully at very high loads and speeds. This erratic behaviour was attributed to a lack of "oiliness," and the Amsler test points to a remarkable difference between silver and copper-lead alloys in this respect. "Oiliness," which may be defined as the tendency of certain parts of the oil to adhere strongly to the metal and prevent metal-to-metal contact is not a function of the lubricant alone, but rather of the lubricant, bearing metal, and shafts. Considered in this way, it is evident that a lubricant which has "oiliness" on a bronze bearing may not have it on a silver bearing.

It was found that this property of oiliness was determined from Amsler testing by comparing the results obtained from a ground shaft with those obtained with a polished shaft. When oiliness was present, a bearing worked equally well with both shafts, but when oiliness was absent the seizure pressure against ground shafts was much lower than against polished shafts. When tests with the three standard alloys were made against both types of shafts, the results given in Table III were obtained.

TABLE III.

Alloy.	Relative Seizure Pressures. Highly Polished Shaft. %	Ground Shaft. %
Electrodeposited Silver	165	35
Cu 71, Pb 18, Ag 1	100	100
Cu 72, Pb 25, Sn 3	75	75

It is believed that this oiliness, lacking in silver bearings, is a necessary property of a bearing material, and that if it is lacking the bearing cannot get past periods in which some temporary event tends to lead to seizure. Two ways of overcoming this lack of oiliness have been experimented with. The first was to alloy silver with some element, such as lead or sulphur, which formed a separate phase exhibiting oiliness effects, and the other to blend the oil with some additional agent, such as sulphur, which wets the surface of the silver. Both methods were tried, as was also the electroplating of the silver and silver-lead alloys and from the data obtained a distinct improvement was shown in the oiliness property by all methods and particularly with a 6% cast lead-silver alloy.

The Institute of Metals

Annual General Meeting in London

THE thirty-first annual general meeting of the Institute of Metals was held in the Hall of the Institution of Mechanical Engineers on March 8 and 9, with the President, Dr. C. H. Desch, F.R.S., occupying the chair. At the opening meeting an early opportunity was taken by the President to welcome overseas members; particular reference was made to Dr. Max Hansen, representing the Gesellschaft fur Metallkunde, and the corresponding member for Switzerland, Dr. von Zeerleder, also Professor Breckpot, of Louvain University, M. Gaston Gauthier, of Chambery, France, and Dr. Leopold Frommer, of Berlin.

The report of the Council, presented in abstract by the Secretary, shows how this Institute is progressing. Particular mention was made of the improved facilities afforded by the co-operation with the Iron and Steel Institute in the new headquarters at No. 4, Grosvenor Gardens; to the amalgamation of the two libraries, and to the substantial increase in membership. Comment was made on the disappointment felt at the cancellation of the visit to Canada and the United States on account of the European crisis, and reference was made to the Endowment Fund, which is hoped to be completed shortly. The report was a very satisfactory one.

The hon. treasurer, Mr. John Fry, presented the accounts of the Institute, and pointed out that one of the difficulties is to keep the expenditure within the bounds of income; during the year income exceeded expenditure by £83, while £3,200 has been added to the capital account. The President moved that the very best thanks of the Institute be given to members of the Council and to the Hon. Treasurer, for the work they had done during the past year, a motion which was carried unanimously.

The Institute of Metals Medal

Following the election of officers, the President had the pleasant duty of presenting to Sir Harold Carpenter the Institute's Platinum Medal, which is placed at the disposal of the Institute by the Mond Nickel Co. In making the presentation, Dr. Desch said that Sir Harold's association with the Institute of Metals has been very intimate, he having been one of the original members, and one of the most active. During many years as a teacher, first in Manchester and then in London, he has directed schools of metallurgy in which he has trained men who have since distinguished themselves in metallurgical work. In addition to his great reputation as a teacher, he is not less known as an investigator, and while much of his research work has been done on the ferrous side, he has carried out a large amount of work on non-ferrous metals, particularly the valuable results he obtained on the subjects of grain-growth, recrystallisation, and the properties of single crystals.

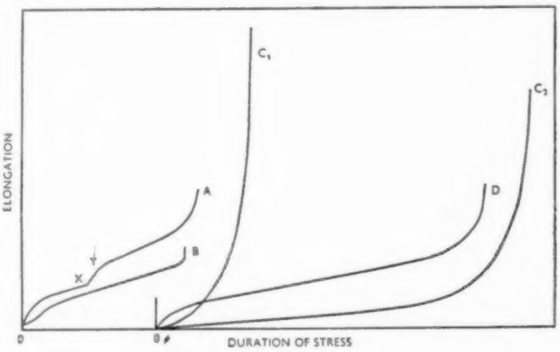
Sir Harold Carpenter, in replying, recalled last year when the award of this medal for the first time was made to Sir William Bragg, and his feeling of sadness that Mr. Barclay, who presented the medal, is now deceased. He regarded it with particular pleasure that the medal should be handed to him by Dr. Desch, whom he looked upon as a metallurgical brother. After referring to the history of platinum, Sir Harold said he felt he had been privileged to work at a very interesting period in the development of the science which is now usually called physical metallurgy. He mentioned outstanding investigators of international fame with whom he had had personal contact. Much of his work, he said, had been done in association with others, and they share this honour, but he desired to include one in a different category, that of Lady Carpenter, who by her encouragement and support had sustained him. He felt that they all shared with him the honour of this medal.

TECHNICAL SESSIONS

Several papers were presented on a wide range of subjects, the majority of which resulted in considerable discussion; the general discussion on the effect of work on the mechanical properties of non-ferrous metals in particular was both interesting and informative, lack of space, however, prevents us presenting other than a brief summary of the papers here.

Types of Creep Curve obtained with Lead and its Dilute Alloys

IN the course of investigations of the behaviour of rolled lead and its dilute alloys under stresses of 350 lb. and 500 lb. per sq. in., four distinct types of creep curves were obtained. The types of creep curve obtained, reproduced here, are lettered A, B, C and D respectively. Type A shows strain-hardening, and after a certain stage there is a marked increase in creep rate owing to recrystallisation. Type B shows initially an increase in creep rate and then strain-hardening, but no recrystallisation. This type is accompanied by intercrystalline failure. Type C shows a continuously increasing creep rate which is held to be associated with loss of cold-work hardness during the test and also with an increase in the proportional limit as compared with the basis lead. Type D is a normal strain-hardening variety, characteristic of metals which are below the recrystallisation range of temperature.



Types of Creep Curve.

These curves are examined in a paper by Dr. J. Neill Greenwood and Mr. Howard K. Worner, in an effort to suggest reasons for their major characteristics. Curves illustrate the effect of stress and composition, initial cold-working, and grain size. In both the latter the examples are merely to indicate complexity and are not exhaustive.

As a result of an extensive range of investigations, the authors conclude that creep is partly a viscous flow and partly a plastic flow. The limit of proportionality can be taken as an approximate guide to the critical stress above which the crystalline component becomes effective. Above the critical stress, pure lead and certain dilute alloys give a strain-hardening type of curve showing a marked deviation due to the increase of creep rate during recrystallisation. The degree of purity of "pure" lead and the elements present as impurities have a marked influence on the creep rate above the critical stress and on the percentage of strain required to cause recrystallisation under stress.

If lead is quickly cooled from 120°–130° C. and a creep test (over the critical stress) is started within two days, the curve shows an initial increasing creep rate followed by strain-hardening. There is no recrystallisation, and the

piece fails by intercrystalline cracking. A reversion to type A or D occurs if the specimen is allowed to stand at ordinary temperatures before stressing. The addition of solute atoms to lead causes a change from type A to type D curve, the lattice being stabilised. There is then no recrystallisation during the test. If an alloy is cold-worked and the work-hardness is lost during the test, a continuous increase in creep rate is found—type C curves. This type of curve is also associated in an undetermined manner with the presence of certain solute atoms. With pure lead above the critical stress, the grain-size, if between 0·5 and 5 mm. diameter, has little effect on the creep rate prior to recrystallisation.

Creep is complicated in many ways by the presence of solute atoms. For example, grain-size, hardness, and work-hardening capacity are all changed. Neither hardness nor work-hardening capacity is a criterion of the behaviour under prolonged stress. In certain cases the rate of recovery after work-hardening is an important factor. Another complexity arises from the mode of distribution of the added element—this may form a solid solution or eutectic or may exist as primary crystals either in the elementary or combined form. Two important problems must be further considered : (*a*) the influence of solute concentration, and (*b*) the influence of degree of dispersion of a second phase. Solute atoms may cause an increase or a decrease in the creep rate above the critical stress. Vibration markedly increases the creep rate and causes recrystallisation to take place after smaller amounts of deformation. Recrystallisation under stress is less liable to take place the larger is the grain-size.

Annealing Characteristics and Solid Solubility Limits of Copper and Copper Alloys containing Chromium

COMPARATIVELY recently interest has arisen in the use of chromium as an addition to copper and copper-base alloys. Investigations have shown that the most consistent and noteworthy effect of these additions on the properties of copper-base alloys is their very marked restrictive influence on the recrystallisation and grain-growth of the cold-worked alloys. Dr. W. O. Alexander, in this paper, shows that small additions of chromium—e.g., 0·3% to copper, 0·04% to brass, and 0·15% to aluminium bronze—restrict grain-growth on annealing at temperatures up to 700° C., slightly greater amounts being required at higher annealing temperatures. When added to cupro-nickel alloys, the effect is not so marked.

As a result of investigations described in this paper, the author concludes that chromium increases the softening temperature and markedly restricts the grain-growth of copper, aluminium bronzes, brasses, and cupro-nickels, which influence is so effective that the softening temperature of copper is increased from 200°–300° C. to 300°–400° C. in the presence of 0·3% chromium ; further, after annealing this alloy at 800° C. the grain-size is 0·005 mm., while an alloy containing 0·73% chromium restricts grain-size at 900° C. to 0·01 mm. Similarly, 0·25% chromium in 7% aluminium bronze increases the softening temperature from 500° to 700° C. and limits the grain-size at 700° C. to 0·01 mm., the corresponding chromium-free alloy having a grain-size greater than 0·1 mm. at this temperature.

In the 70 : 30 and 80 : 20 cupro-nickels, up to 0·25% chromium in the former and 0·29% chromium in the latter do not appreciably affect the hardness of the alloys, the softening curves being very similar. Increase of chromium content to 0·45 and 0·54% increases the softening temperatures by about 30° and 50° C. respectively. In applications where copper alloys are likely to develop large grain-sizes due to cold-work and subsequent annealing at high temperatures, the addition of chromium will markedly restrict grain-growth, so that only normal grain-sizes may be developed. The restrictive action of chromium on grain-growth is attributed to precipitation of chromium from solid solution and mechanical obstruction at the grain boundaries.

The Elastic Properties of some Anti-Friction Alloys at Room and at Elevated Temperatures

NUMEROUS papers have been published on the tensile and compressive properties of tin-base bearing alloys, but with probably one exception, little data are available on the plastic properties of anti-friction alloys. A relatively large number of room-temperature tensile curves have been published, but unless the experimental conditions of the cases are identical, the elastic portions of these curves cannot profitably be compared. Little information in literature is available on the plastic moduli of these materials, especially at elevated temperatures.

The investigation described in this paper by Mr. J. W. Cuthbertson, was originally put in hand to supply the data lacking on the properties of the white metal, and so to allow these stresses to be computed. The alloys examined include high-tin, high-lead, and intermediate types, and an attempt has been made to correlate elastic modulus, chemical composition, and temperature. The effect of cadmium and of lead additions to the copper-antimony-tin alloys has been studied in detail, and the Brinell hardness numbers and Hargreaves' "S" values of the whole series of alloys have been determined. A plane-bending test with interferometer deflection-recording mechanism was adapted to the determination of the elastic moduli. All the materials examined creep under relatively low stresses, but obey Hooke's law if the load is applied with sufficient rapidity. A standardised rate of loading was therefore adopted throughout.

There is little difference between the elastic modulus-temperature curves of the high-tin alloys, although E tends to increase as the antimony content is increased. Lead, even in small quantities, alters the shape of the curve and leads to failure by creep at or near the melting point of the lead-tin eutectic. Cadmium in amounts up to 1% has apparently little effect. Above 50° C. and almost up to the melting point, the curve for tin falls linearly, but less steeply than the curves for the tin alloys, and intersects the latter in the vicinity of 210° C.

The lead-base alloys have lower elastic constants than the true Babbitts, and, with the exception of Bahnmetall, fail by creep at, or well below, 180° C. The elastic modulus of Bahnmetall at room temperature is lower than that of any other alloy, but the elastic properties are maintained quite well at the higher temperatures ; the elasticity is seriously impaired, however, by remelting and by surface corrosion.

The Influence of Static Stress and Heat-Treatment on the Intercrystalline Corrosion of some Wrought Aluminium Alloys

IN studying the alloys of aluminium, investigators have found that the heat-treatment given to the material is an important factor controlling the incidence of intercrystalline attack. It is concluded that while material quenched in cold water is generally not susceptible, certain alloys when more slowly cooled are susceptible to intercrystalline attack. Some work on intercrystalline failure under static stress on certain aluminium alloys, which has been carried out at the National Physical Laboratory for the Metallurgy Research Board of the Department of Scientific and Industrial Research, is described by Messrs. J. D. Grogan and R. J. Pleasance.

Certain aluminium alloys containing zinc are unusual in that, when suitably heat-treated, they fail in air under torsional stress without the deliberate application of any corroding agent. No visible corrosion occurs, the fractured surfaces remaining quite bright. Alloys of this type were studied, most of the work being carried out on an alloy containing 3% copper and 20% zinc. The alloys were made up in the form of wrought heat-treated strip, and the influence of heat-treatment on their sensitivity to intercrystalline failure was examined.

The copper-zinc-aluminium alloy, containing 3% copper and 20% zinc, when given a solution heat-treatment at 450° C., is a simple solid solution, and in this state is susceptible to intercrystalline cracking. Re-annealing at lower temperatures, which allows the precipitation of copper, does not remove this susceptibility. Annealing at a still lower temperature, which allows zinc as well as copper to be precipitated, definitely reduces, but is not shown to eliminate, this susceptibility. The presence of copper is not essential to the process. Certain alloys containing zinc alone were found to fail both in air and in sodium chloride solution. The method of cooling after the solution heat-treatment exerts a considerable influence on the susceptibility, sheet cooled in air being distinctly more sensitive than that quenched in cold oil. The time needed for fracture to occur increases rapidly with decrease of the applied load. However, no lower limit of stress below which failure does not occur has been detected, and intercrystalline attack takes place in salt solution in the absence of externally applied stress. In this respect these alloys differ from the α brasses.

The intercrystalline corrosion of 3/20 copper-zinc alloy stressed in salt solution appears to be exactly similar to that in air, except that failure occurs much more rapidly in the liquid. Failure in air appears to be due to selective attack of the grain boundaries by some constituent of the atmosphere; in some experiments in which material was subjected to stress in the absence of air failure did not occur: subsequent exposure to stress in air produced fracture in the normal way.

Microscopical examination of polished material stressed by dead loading shows that fine intercrystalline cracks develop at the surface of the test-piece and spread without visible distortion of the adjacent metal until the reduction of cross-sectional area of the uncracked metal has considerably raised the imposed stress. At this stage slip bands may develop in the crystals round the root of the crack and a certain amount of distortion may occur. Shortly after this stage rupture occurs, the fracture being almost entirely intercrystalline even when the load is high. Sea-water spray tests on "Y" alloy and 4% copper alloy loaded in tension have emphasised the great importance of the method of cooling the metal after solution heat-treatment. Rapid cooling, such as quenching in cold water, rendered the metal immune to intercrystalline attack, and in such cases static stress does not influence the loss of strength due to corrosion. The presence of particles of $CuAl_2$ of microscopic size precipitated in the grain boundaries of the 4% copper alloy does not appear to influence corrosion. Relatively slow cooling—e.g., in air—renders the material very susceptible to intercrystalline attack, which is hastened by imposed stress; such stress, however, is not essential to the development of intercrystalline attack.

Embrittlement of Tin at Elevated Temperatures and its Relation to Impurities

It is commonly stated that tin becomes brittle at elevated temperatures of the order of 200° C., and may readily be powdered in a mortar. This phenomenon of cracking and brittleness is of some scientific and practical interest, not merely in connection with pure tin, but also in connection with tin-base alloys, such as white-metal bearing metals. The investigation described in this paper by Dr. C. E. Homer and Mr. H. Plummer, was designed to study systematically the relation of this embrittleness to the various impurities which may be present in commercial tin, and to plan the work in such a way that the results would also provide a basis for a future investigation on bearing metals.

The results of the investigation show that the embrittlement of tin at elevated temperatures is not a property of the pure metal, but is caused by the presence of impurities. The latter form eutectics or solid solutions which fuse at temperatures below the melting point of tin, and thus lead to intergranular fracture. By means of a simple bending test, the temperature at which brittleness first occurs has been determined for both cast and annealed specimens of tin containing additions of lead, copper, bismuth, cadmium, silver, zinc, iron, antimony, or arsenic. In each case the temperatures may be correlated with the solidus of the equilibrium diagram, and it is shown that in many cases the method may be employed to determine the solidus lines quickly and accurately. Solidus lines have been determined in this manner for the tin ends of the systems lead-tin, copper-tin, cadmium-tin, silver-tin, and zinc-tin, and certain new values are given for limits of solid solubility. The effects of adding two or more impurities simultaneously to tin have been investigated. A study has been made of the distribution of lead in tin and of the rate and manner of dissolution and reprecipitation of the lead-tin eutectic on heating and cooling certain tin-rich alloys. The Brinell hardness of pure tin has been determined over a range of temperature between 0° C. and the melting point, and the curve shows no inflections.

Whilst the brittleness of tin on heating has been known for many years, it has hitherto been explained by assuming the existence of a brittle allotropic modification, stable at elevated temperatures. This modification, known as γ-tin, is considered to crystallise in the rhombic system, whereas the normal form of tin is tetragonal. The existence of γ-tin has always been doubtful, and is discussed at the conclusion of this paper, in the light of the results obtained in the present work. The authors conclude that this modification does not exist, and that many of the effects previously ascribed to it have been caused by impurities.

On the Theory of the Origin of Rolling Textiles in Face-Centred Cubic Metals

The study of the plastic deformation of face-centred cubic metals, from a crystallographic point of view, is discussed in this paper by Dr. M. R. Pickus and Professor C. H. Mathewson, and reference made to the work of several investigators commencing with that of Taylor and Elam in 1923. Arising from a consideration of the work accomplished, the authors have developed a new theory which not only appears to account for all the rolling textures that have been observed in face-centred cubic metals, but also assigns to each a relative degree of importance.

An X-Ray Investigation of Cobalt Aluminium Alloys

The cobalt-aluminium equilibrium diagram, which was first investigated by Guillet, has not been completely revised since the pioneer investigation of Gwyer, who found five phases. Further work on this system is presented in a paper by Dr. A. J. Bradley and Dr. G. C. Seager, in which is reproduced the phase diagram given by Hansen, based on Gwyer's work and revised to include some results by Köster on alloy containing between 70 and 100% cobalt. More recently, Köster and Wagner have examined the influence of the addition of aluminium on the transition temperature of cobalt. The results given in the present paper lead to different conclusions in this respect.

The authors conclude that aluminium dissolves in the cubic form of cobalt, but not in the hexagonal. It tends to preserve the cubic structure on cooling. After annealing at 320° C. for several days, some of the dissolved aluminium is precipitated as CoAl, and the residual cobalt is converted to the hexagonal form. CoAl, which has a body-centred cubic structure, dissolves both cobalt and aluminium. The lattice spacing, which is a maximum at the ideal composition, falls slowly on the cobalt side, but more steeply on the aluminium side. As in the analogous case of NiAl, this is due to the rejection of atoms from the unit cell, when there is less than 50% cobalt. In these alloys there are aluminium atoms at all cube corners, but the cube centres are deficient in cobalt atoms.

Four aluminium-rich phases have been found. Co_2Al_5 has a hexagonal structure containing 28 atoms per unit cell.

The existence of a phase of composition CO_3Al_{13} or Co_2Al_9 has also been confirmed. The addition of cobalt to this phase does not give a mixture with Co_2Al_5, as has previously been supposed. The phase in equilibrium with Co_3Al_{13} has the approximate formula Co_3Al_{13}. It has a very complicated X-ray pattern, which is quite different from those of either CO_3Al_{13} or Co_2Al_5. Photographs of alloys near the composition $CoAl_3$ indicate the existence of yet another phase, but this has not been isolated. This work is being continued as part of a general scheme of investigation on magnet alloys, in co-operation with the Permanent Magnet Association and the British Electrical and Allied Industries Research Association.

Some Observations on the Forging of Strong Aluminium Alloys

ALTHOUGH problems connected with the design, the choice of alloy, and the technique in casting strong aluminium alloys have been dealt with extensively in literature, little fundamental work has yet been recorded on the fabrication of parts in these alloys by forging, and especially on their properties. Forged parts are usually regarded as having substantially better properties than those which are cast, say, 50 to 75% better. For the majority of applications this view is undoubtedly correct, but experience with a number of forged parts made under exacting conditions has shown that great caution is necessary in putting forward such claims for them.

Many fundamental factors on the forging of these alloys are considered in this paper by Professor Dr. George Sacks, in which he discusses in detail the mechanical properties of forgings, which are generally different in three directions. These properties depend on many factors, the most important of which are stated to be the shape of the forged part, the properties of the alloy and the stock, and the design of the dies.

It would appear that, in general, alloys which are difficult to fabricate as sheets, etc., on account of a certain amount of brittleness, can give rise to considerable difficulties in forging. The harder the alloy, the greater is the scatter in the ultimate tensile stress and elongation values in the transverse direction, and the greater is the difference between the properties in the longitudinal and transverse directions. In specially tough alloys, possessing a high reduction of area when tested in tension, these differences in the ultimate tensile stress and elongation disappear, but they still persist to a high degree in the reduction of area and in the notched-bar impact values. The hardness and proof stress, on the other hand, are constants for a given alloy in a definite condition : they have always the same values in the longitudinal and transverse directions.

With aluminium alloys of high strength it is necessary to impose deformation to the extent of 80 to 90% at least, depending on the nature of the process, in order to obtain the normal structure with high mechanical properties. Heterogeneous inclusions invariably render forging more difficult, in that they promote the formation of cracks. In practice, however, alloys of this type, such as Lo-Ex, are forged ; this alloy contains 12% silicon, and 1% each of copper, magnesium, and nickel, and almost 20% of its volume consists of heterogeneous inclusions. These alloys find special application as pistons for aircraft engines : they are inherently very soft in forging and fill the dies well, although irregular flow and any tensile stress may lead at once to fracture, since highly heterogeneous alloys are sensitive to tensile and also to shear stresses.

The author discusses the changes of mechanical properties in forging discs and bars by different methods, and states that the properties of shaped forgings are determined mainly by the properties of the stock and the local deformations. The most serious defects in forgings are cracks in the flash, at the base of ribs, and on the surface of expanded parts. These can be avoided by more or less radical changes in forging practice. Problems associated with heat-treatment are discussed.

A Comparison of the Extrusion Properties of some Aluminium Alloys

THIS paper by Mr. C. E. Pearson describes an extension of previous work[1] to some aluminium alloys. In the earlier work by the author and Dr. Smythe an extrusion apparatus was described by means of which the system of flow during extrusion of some metals of low melting point was traced, and a relationship found between the pressure and rate of extrusion at a series of temperatures. In the discussion of these results it was suggested that the range of experiments might be extended to cover speeds comparable with those used in practice, and that a relation should be sought between the pressure and temperature of extrusion. An attempt to meet these suggestions is the purpose of the work described, in which a comparison has been made of the behaviour during extrusion of aluminium and that of its alloys containing 1·5, 2·5, and 5·0% copper, 1·25% copper, 10% zinc, and 5% zinc.

The pressures required for extrusion at a fixed rate by the inverted method have been determined experimentally for different temperatures, and the existence of a simple relationship between the pressure and temperature of extrusion has been confirmed. Evidence is given to show that the comparison obtained can reasonably be extended to cover rates of extrusion approaching those used industrially. The system of flow in the billets has been studied at different rates and temperatures. The influence of the extrusion temperature upon the mechanical properties of the alloys has been determined.

The author concludes that the difficulty of extruding of copper-aluminium alloys increases with the copper content. In the range of temperature covered it is relatively greater in comparison with aluminium at high than at low temperatures, probably as the result of the increase in the solid solubility of copper. The effect of addition of 5% zinc on aluminium is to reduce slightly the necessary extrusion pressure over the entire range of temperature. Alloy CuZn has extrusion properties which are almost identical with those of aluminium. The relation between extrusion pressure and temperature reported by Shishokin[2] is shown to hold good for the present alloys.

It is considered that the comparison made in the extrusion behaviour of the alloys is not greatly affected when the rate of extrusion is increased about twenty times. The manner in which flow occurs in the billets during extrusion is practically unaffected by variation in the speed and temperature of working, nor does it appear to be influenced by the composition of the billets.

The mechanical properties of the alloys depend to a marked extent on the temperature of extrusion. In the case of aluminium and Zn 5·0, the values for hardness, proof stress, and maximum stress fall as the working temperature is raised and the elongation rises to a maximum and then decreases. In the alloys containing copper these changes are counteracted, to an extent depending on the copper content, by an effect which tends to raise the strength and hardness and reduce the ductility.

Industrial Application of Spectography in the Non-Ferrous Metallurgical Industry

IN the past five years over a hundred investigators have published papers on spectrochemical analysis, most of which have contributed something of greater or less importance to the subject, and the metallurgist, whether he is concerned with high-purity or commercial copper, lead, nickel, platinum, or other metals, brasses, bronzes or alloys of aluminium and magnesium, can readily find well-tried data for spectrochemical analysis. It is therefore noteworthy that a general discussion should be arranged at this meeting on spectrochemical analysis. The subject was introduced by Mr. F. Twyman, who, in this paper, describes the principles of spectrographic analysis which have become generally accepted, and the modern methods

1 C. E. Pearson and J. A. Smythe, *J. Inst. Metals*, 1931, 45, 345.
2 W. P. Shishokin, *Zhur. Priklad. Khimii*, 1929, 2, 663.

of putting them into effect. Particular attention is directed to the principal developments of the past five years or so, and the author sets forth problems affecting accuracy and consistency of results which still require investigation.

The Effect of Composition and Constitution on the Working and on some Physical Properties of the Tin Bronzes

LITTLE published information is available on the working properties of the bronzes, and there appears to have been no previous systematic investigation. The work, described in this paper by Mr. R. Chadwick, was decided, therefore, to investigate the whole series of straight bronzes with a range of tin content up to 30%, and at the same time to study the effect of phosphorus additions to the alloys. The most suitable temperature for the breaking down of the cast structure was determined by forging small cylinders and observing the amount of cracking obtained.

Small slabs of each alloy were rolled in the most suitable temperature range, as indicated by the forging tests, and ultimately the whole series of alloys with tin up to 25% was obtained in the form of thin strip, with the exception of a range from about 17–19% tin which could not be successfully fabricated. Micro-examination was first made of straight tin-copper alloys in the form of thin strip quenched from temperatures corresponding to the phase areas in the accepted tin-copper equilibrium diagram ; the effect of phosphorus additions on the phase changes was then explored. An examination of alloys quenched from 600° C. gave sufficient data on which to base a ternary diagram at this temperature.

Work-hardening by cold-rolling, tensile strength in the soft and hard-rolled conditions, and also hardnesses have been determined on a number of typical alloys covering the whole range of tough materials prepared. The examination of alloys near the α phase boundary—i.e., those containing 13–16% tin, has been made in greater detail. These alloys gave the maximum strength obtainable in the series.

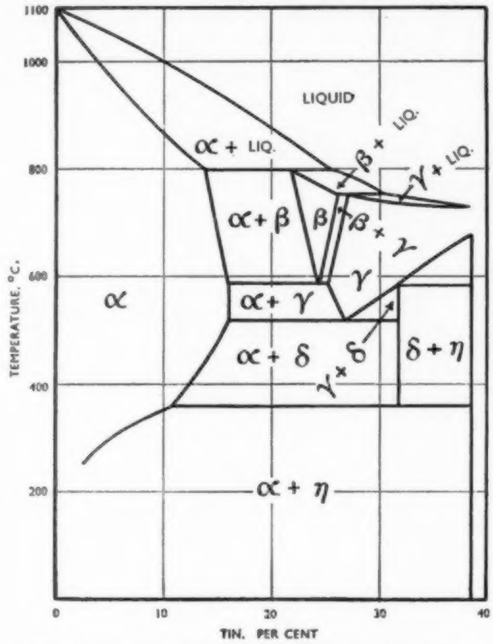
The Effect of Drawing on the Hardness and Tensile Strength of Brass Rod

THE investigation described in this paper by Dr. Maurice Cook and Mr. G. K. Duddridge was undertaken to obtain an indication of the extent to which hardness and strength vary over the section of extruded and drawn rods, with the object of gaining information which might be of use not only in the consideration of tests or specifications, but also to those who use materials of this kind. In the first instance, the investigation was confined to a fairly complete study of the hardness distribution, but it was subsequently extended to include observations on the distribution of tensile strength. The investigation embraces a detailed study of the hardness distribution over the cross-section of typical drawn brass rods from ½ in. to 2½ in. diameter. The tensile strength distribution over the cross-section of 1¼ in. and 2½ in. diameter manganese-bronze rods has also been examined.

The results, which have been considered in connection with the application of tensile and diamond pyramid hardness tests to this class of material, indicate that in drawn rods the extent of the hardness variation depends on the size of the rod and the degree to which it has been cold drawn. In the larger rods examined it ranged up to about 50 D.P. hardness points. In rods in the soft or extruded condition the change in hardness over the cross-section is negligible, what little there is being confined to a narrow zone near the surface. Irrespective of the condition of the rod, the hardness at a distance of $\frac{R}{\sqrt{2}}$ or $0 \cdot 7\ R$ from the centre of the rod has been found to be practically the same as the mean hardness of the rod.

On 1¼ in. diameter rod, drawn with an 18·5% reduction, the greatest variation noted in tensile strength over the cross-section was 6·2 tons/in.^{2}, and on 2½ in. diameter rod, drawn with a 4·7% reduction, 3·65 tons/in.^{2}. Impact values, as determined on the Izod machine, decreased from the centre of the rod towards the surface.

Tests on specimens cut from 2½ in. diameter rod in both the extruded and the drawn conditions showed that the highest values for tensile strength, elongation, and impact were obtained on test-pieces cut parallel to the axis of the rod, with the lowest values on transverse test-pieces, and intermediate values on test-pieces cut at 45°.



Portion of tin-copper equilibrium diagram.

With regard to the bearing which the results have on normal testing procedure, it would seem that when the diamond pyramid, or a similar, hardness test is applied to material of the kind under consideration, informative results can only be obtained on other than soft rod, or rod in the extruded condition, if tests are carried out on at least three positions over the cross-section. With rods too large in diameter to admit of testing in full cross-section a close approximation to the average tensile strength would be obtained with test-pieces cut eccentrically as near as possible to the outside of the rod.

The Vapour Pressure of Zinc in Brasses

IT has long been realised that a considerable vapour pressure of zinc in solid brass must exist below the melting point, and that the changes occurring at the surface, in particular when the brass is heated for annealing or other purposes, must be due in a large measure to this cause. The vapour pressure of zinc must therefore be of special interest in relation to the bright annealing and smooth surface finish of brass. The investigation described in this paper by Mr. R. Hargreaves has been carried out to determine the vapour pressure of a wide range of zinc-copper alloys over an extended range of temperature up to within 25° C. of the melting point.

The pressures of zinc vapour in equilibrium with zinc-copper alloys containing from 1 to 51% zinc and in equilibrium with some aluminium brasses and nickel brasses were determined. The lower limit of temperature was such that the vapour pressure of zinc was only about 1 mm. mercury. Extrapolation to considerably lower temperatures will probably be reliable, especially in single-phase regions, in view of the linear form of the pressure-temperature relationship. The effect of loss or gain of zinc on the surface finish was also examined.

Progress in the Iron and Steel Industry

CONSIDERABLE attention was given in the January issue to developments in the facilities for meeting demands for iron and steel; several reports were incorporated, reviewing briefly the steps taken to improve the capacity of plants during 1938. A further report has come to hand which concerns the activities of the Wellman Smith Owen Engineering Corporation, Ltd., which indicate several additional directions in which progress has been made in the iron and steel industry.

The outstanding centres of activity were the new works of Messrs. Richard Thomas and Co. at Ebbw Vale, and the works' extensions at the Appleby Frodingham branch of the United Steel Companies, Ltd. At the former works, in addition to the installations previously referred to, three 75-ton open-hearth furnaces, to designs provided by Messrs. H. A. Brassert and Co., have been built, together with two heavy type open-hearth furnace-charging machines, two 15-ton scrap-handling magnet cranes, two 10-ton lime-handling cranes, two 9-ton ingot strippers, and two 9-ton vertical ingot charger cranes, also a large installation in the rolling mills, consisting of a continuous normalising and annealing furnace and two complete continuous strip-pickling lines, with conveying systems, tanks, piping, and all subsidiary equipment.

For the Appleby Frodingham Steelworks three ladle cranes of 125 tons lifting capacity have been supplied, also two 4-ton ground type revolving open-hearth furnace-charging machines, one 8-ton ingot stripper crane, one 8-ton slab-charging machine, also one 50-ton and two 20-ton overhead travelling cranes for the new blast-furnace blowing-house. Blast-furnace skip hoists and a complete set of coke-oven machines for the new Koppers coke-oven battery, have also been supplied.

Further important contracts for the supply of cranes and charging machines have been carried out by the Wellman Corporation for the Lancashire Steel Corporation, Messrs. Steel, Peech and Tozer, the Redbourn works of Messrs. Richard Thomas and Co., and others. A complete open-hearth steel plant with gas producers, all buildings and subsidiary equipment, has been built to the order of the Blaenavon Co., Ltd., and many continuous billet-heating forge, heat-treatment, and other types of furnace have been supplied.

A large number of gas producers of the Wellman mechanical and Wellman-Galusha types, for dealing with bituminous coals, also coke and anthracite, have been put up in steelworks and different industrial undertakings.

On the coke-oven machinery construction side, considerable activity has been apparent. In addition to the Appleby Frodingham installation already mentioned, complete sets of Wellman machines have been supplied to the orders of the Woodall-Duckham Co., for the batteries built by them for Messrs. Richard Thomas and Co. at Ebbw Vale and Redbourn. The Coking and By-Products Co., Ltd., Hemsworth installation is also to be equipped with Wellman machines now in the course of erection.

In spite of this activity at home, the importance of maintaining contact with foreign and colonial markets has not been overlooked, and as the result of a progressive policy important contracts have been secured for steelworks and coke-oven machinery for Belgium, Holland, Russia, etc. Large installations for the manufacture of weldless steel tubes, comprising hydraulic presses, push benches, sizing and straightening mills, conveyers, furnaces, and subsidiary equipment have been delivered to South Africa, Australia, and Italy. A considerable number of electric locomotives have been manufactured and despatched principally to Canada and Australia. For the Turkish Government, the Corporation are carrying out to the order and design of Messrs. H. A. Brassert and Co. the construction at Karabuk of three large open-hearth steel furnaces, reheating furnaces, and various supplementary equipment. Assembly of the two giant creeper cranes of Wellman design to be employed in the erection of the new Howrah Bridge in India, is now in full progress at the works of the Cleveland Bridge and Engineering Co., Darlington.

Amongst other contracts in hand, the Corporation is at present engaged in the supply of cranes and strip steel pickling equipment for the new sheet mill works of Messrs. John Summers, Ltd., a further 300-ton tilting type open-hearth furnace, and 600-ton metal mixer for the Appleby Frodingham Co., a 600-ton metal mixer for Colvilles, Ltd., and complete sets of coke-oven machines for the batteries under construction by the Woodall-Duckham Co. for Colvilles and Stanton Ironworks.

A battery of annealing and heat-treatment furnaces with gas plant, probably one of the largest in the world, has also just been completed in the North, particulars of which cannot yet be given; other Wellman plant has been supplied during the past year, details of which are not available for publication.

Development in the Donets Basin

By a Special Correspondent.

THE Donets Basin occupies practically the entire south-eastern part of the Ukraine and a small, section of the Rostov Province. Sixty-five per cent. of the total volume of coal raised in the Soviet Union comes from the Donets Basin, which is also responsible for 37% of the total quantity of pig iron and 13% of the electric power produced in the Union.

During the period 1928–1937, 300 new plants were built in the Ukrainian part of the Donets Basin alone. Nearly 7,000 million roubles were invested in the region during the first 18 years of the Soviet regime. As compared with 1913, production in the Donets Basin has increased by more than sixfold. A fact of importance is that 96·2% of the entire industrial output of the Donets Basin is turned out by plants constructed since the establishment of the present regime.

Scores of large mines have been put into operation, equipped with the most up-to-date equipment. The old collieries are unrecognisable. Whereas all mining operations before the establishment of the present regime were performed by manual labour; the mines in the Ukrainian part of the Donets Basin, on January 1, 1938, possessed 1,552 large coal-cutting machines, 7,563 pneumatic picks, and 520 electrically hauled cars. By 1937, 89·2% of the processes of coal raising in the Donets Basin had been mechanised.

Iron and Steel

The Azovstal iron and steel works has grown up in the city of Mariupol, on the Azov Sea. This plant works on iron ore brought from Kerch (in the Crimea) by sea. Tilting open-hearth furnaces (each of 250 tons), the first of their kind in the Soviet Union, have been installed at this plant.

The Kirov iron and steel works at Makeyevka, the reconstruction of which cost 600 million roubles, although officially listed as an old plant, is actually an entirely new enterprise with mechanised blast-furnaces, new open-hearth furnaces (each of 150 tons capacity), and a new blooming mill. Two other iron and steel works in the Donets Basin (the Stalin and Orjonikidze) underwent radical reconstruction. The iron and steel industry of the Donets Basin is not merely limited to plants smelting iron, steel-making, and rolling it into rails, girders and similar products. A large tubing mill was recently constructed at the Ilyich plant, and a zinc works at Konstantinovka.

Electric Energy

The Donets Basin now possesses a powerful network of electric generating stations, producing $2\frac{1}{2}$ times more electric energy than was turned out in the whole of Russia before the war. The second largest electric generating plant—the Zuyevka—is in the Donets Basin, and the Kurakhovka generating plant, now under construction, will be one of the largest in the world.

Recent Developments in Materials, Tools and Equipment

Electron Diffraction and Its Applications

By P. R. WARD.

SINCE G. P. Thomson showed that electrons could be diffracted by an exceedingly thin film, or by the surface layers of a massive specimen,the development of the method into a scientific weapon for the investigation of structural problems not open to X-rays has proceeded rapidly, mainly in the schools led by Thomson and Finch. To-day, electron diffraction is no longer confined to the research laboratories of our universities, but is finding increasing application in those industries which encounter problems connected with surface structure.

Specimens may be examined by reflection, or if the specimens are thin enough, by direct transmission. In the reflection method a fine beam of electrons which have been accelerated through 40-70 k.v. is allowed to fall at grazing incidence on the surface of the specimen *in vacuo*.

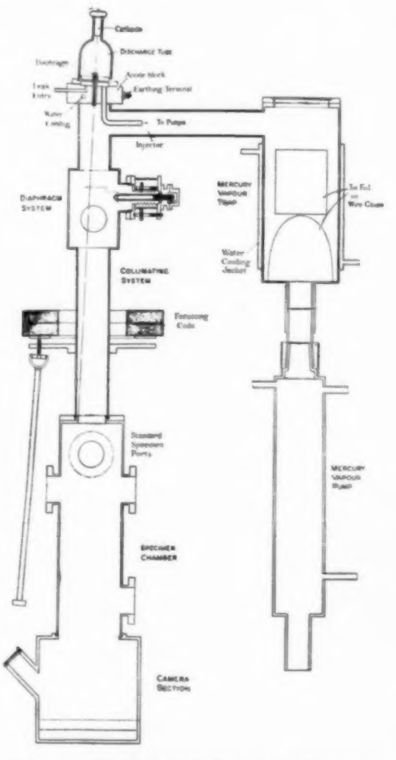


Fig. 1.—General details of an electron diffraction apparatus.

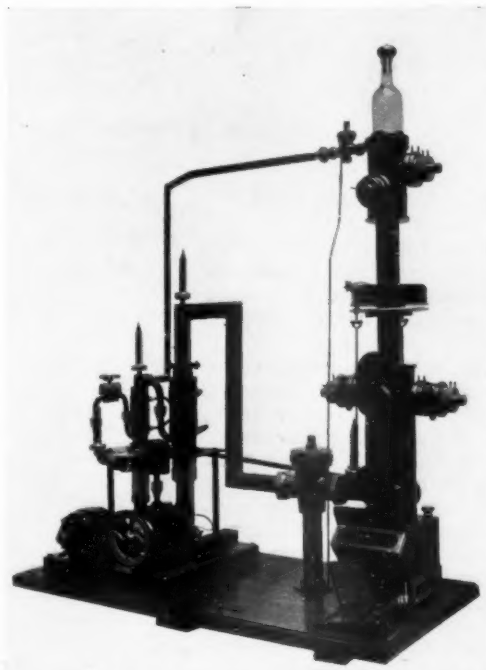


Fig. 2.—An electron diffraction camera incorporating the latest developments and connected to an oil-vapour vacuum equipment ready for use.

The electrons are diffracted on passing through needle-like projections from the surface, and are recorded on a photographic plate, the exposure being a matter of seconds. Almost any surface which has been subjected to mild chemical attack will afford a good pattern and with modern apparatus it is possible to carry out small-scale experiments in the diffraction camera and follow the subsequent changes in surface structure by observation of the fluorescent screen, taking photographs at appropriate stages. The electrons penetrate to a depth of at most 20 Å, and the information yielded by the electron diffraction pattern can be regarded as characteristic of the true surface layers.

As a result of the low penetrating power of electrons the crystals of the specimen surface behave as two-dimensional gratings, and this leads to greatly increased efficiency of diffraction and very short exposure times.

Surface films frequently possess a crystalline structure different from that of the same material in bulk and the existence or otherwise of such an abnormal structure may be the deciding feature in the success of an industrial process. In many cases orientation of surface crystals plays an important role, and it is one of the major advantages of electron diffraction that owing to the small angles of diffraction, the nature of any orientation is at once obvious from the diffraction pattern.

The design of the apparatus by W. Edwards and Co. has fundamentally remained unchanged for several years, and the line drawing shown in Fig. 1 gives the general details. By means of a system of adjustable diaphragms, one of which is shown in the diaphragm system, only those electrons which have not lost energy by collision with gas molecules in the discharge tube are allowed to impinge upon the specimen. The electron beam is concentrated and rendered parallel by the variable axial magnetic field of the focusing coil, and then allowed to fall at grazing incidence upon the specimen held in a universally-adjustable holder in the specimen chamber. The diffraction pattern obtained is visually inspected on a fluorescent screen in the camera section, this screen being rotated in order to record the pattern on a photographic plate. Fig. 2 shows an electron diffraction camera incorporating the latest improvements and connected to an oil-vapour vacuum equipment ready for use.

Models are also available for use with mercury-vapour pumps, and in each case the design is such as to give maximum speed of operation.

Slight alterations to the equipment are made from time to time as more convenient means of operation become apparent, and although the electron diffraction camera described has been designed for general purposes, owing to the large number of ports provided as standard, it is easily possible to adapt the camera to a specific problem. In the choice of specimens for examination, it must be borne in mind that the diffraction camera operates at a very high vacuum, and the specimens must be able to withstand this.

Work is being done and definite results have been obtained in the following fields: The investigation of

effects due to corrosion such as is obtained in contacts, for instance, wear in bearings, pistons, etc., the effect of surface structure upon photo-electric and thermionic emissions, protective coatings, etc.

The technique of electron diffraction is relatively simple, but as with other scientific methods, it is necessary to correlate the results with other available data in order to obtain the maximum information and the application of electron diffraction in this way must necessarily throw considerable light upon many surface problems which are at present only imperfectly understood.

Long-Life Hot Shear Blades

IN the production of the various forms in which steel is marketed, and also in the fabricating equipment for large structures, many problems are encountered as a result of the rapid wear of normal shear blades, dies, punches, rolling mill entry guides, and many other parts of equipment in the iron and steel trades which are subjected to severe service. For some years it has been recognised that the application of Stelliting rod to surfaces, edges and points severely abraded by hot or cold steel, or materials used in steel-making, will result in definite economies. Such a problem is encountered in the rapid wear of hot shear blades.

A batch of Stellited blades for John Lysaght Ltd.

Many different types of steel and iron have been tried for this purpose, but the severe conditions caused by impact and high temperatures have resulted in a short life of the blades and in many cases the cut was anything but clean and satisfactory.

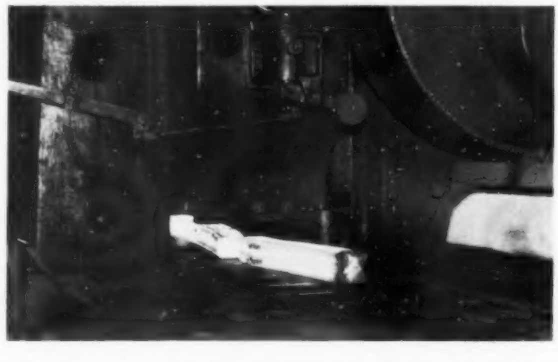
Some time ago experiments were conducted under actual working conditions to see whether Stellite would lengthen the life of blades. Stellite, as many readers know, is a cobalt-chromium-tungsten alloy which has the peculiar property of remaining hard at red heat. After some experimental work to determine the correct shape and area of the deposit of this alloy to form the shearing edge, several sets of blades were subjected to the most severe continuous tests in an endeavour to find whether a real solution of the problem had been found. The results were most gratifying, and gave remarkable increases in the useful life of the blades.

Standard shear blades operating on carbon and alloy steels up to 2 in. square cut only 1,550 pieces before regrinding was necessary. These were then exchanged for Stellited blades, and the number of pieces cut without grinding was 40,900. An ordinary $1\frac{1}{4}$ in. × 3 in. × 10 in. blade guillotine at the same plant fitted with Stellited blades cut 156,930 pieces per grind on stock varying from $\frac{3}{4}$ in. to 3 in. square. At another plant existing shear blades were removed for reconditioning after three shifts. Stellite blades lasted for 72 shifts before showing need of reconditioning.

Since these results were obtained the application has made progress, and further results have been obtained which in many instances give higher figures than those already mentioned. It will be realised, however, that, besides providing a big saving in replacements, maintenance costs are drastically cut, especially as water is not necessary, and consequently the fixing bolts are easy to remove even after the very much longer continuous working periods.

One of the disadvantages with the ordinary shear is the fact that it tends to squeeze the bar rather than to cut it. With Stellited blades, the actual cutting is effected without noise or vibration as a clean shear is maintained throughout the life of the blade. By the new method the saving in steam packing alone is considerable. Only a small amount of Grade 6 Stellite is necessary. A recess $\frac{3}{4}$ in. × $\frac{3}{32}$ in. deep is cut along the face and bottom edge of the blade, so that the alloy can be deposited by the oxy-acetylene process to give complete edge protection. This deposit is then ground before use.

Blades of all types and sizes up to 6 ft. long have been treated, and in every instance the results obtained have represented considerable life increases over the previous methods, in spite of the small quantity of Stellite necessary and the ease of treatment. The alloy is marketed in this country by the Deloro Smelting and Refining Co., Ltd.



Stellited hot shear blades in action at Messrs. Steel, Peech and Tozer.

M-V Strong Magnetic Crack Detectors

STRONG as steel—the phrase is common and significant: but what if the steel be cracked or flawed? The problem is a serious one for engineers in all branches, and much thought and ingenuity have been given to methods of inspection to ensure that only sound material shall be used, especially for parts which will be highly stressed.

In present years a new method of crack detection has been devised which uses as its indicator the concentration of fine particles of iron upon any discontinuity in or near the surface of a magnetised specimen under examination. For very fine cracks it has been found most effective to use a specially-reduced iron dust carried in almost colloidal suspension in dry oil.

As an alternative to methods of dipping a large specimen or flooding it with the prepared fluid a very convenient and useful portable crack detector has now been placed on the market by the Metropolitan-Vickers Electrical Company Ltd., whose research department has taken a leading part in the development of the technique in various forms. The new detector is in the form of a thin hollow disc-shaped container filled with the dust-laden oil and provided with one or both sides transparent so that the concentrations can be observed. It is, of course, applicable only to flat surfaces. For other shapes, the specimen must be immersed in a bath of the fluid.

The method of using the new portable detector is very simple. The specimen to be examined is first magnetised, and the detector is then placed upon its surface, preferably in a horizontal position and gently tapped or rocked. Any crack in the surface is soon—within about 15 to 20 secs.—clearly indicated by a black line formed of the fine iron particles which are attached to the magnetic poles created at the edges of the crack. As with the larger-scale applications the indication is very sensitive and unmistakable, showing even hair-cracks which could scarcely be detected

by ordinary microscopic examination. Each test takes only a few seconds. After the indication has been noted, shaking the detector redistributes the iron dust ready for the next application. Routine tests or elaborate explorations can thus be made very rapidly.

This new portable crack detector is proving very useful both for industrial routine inspection of ferrous materials, and also for instructional work in schools and colleges. Apart from the detection of flaws, it can be used for the study or demonstration of leakage paths in magnetic systems, the magnetic fields associated with current-carrying conductors, the effects of work-hardening of steels, and many other magnetic and metallurgical problems. It can even be used to indicate the presence of electrostatic fields.

The detector is sold at 10s. 6d., and is supplied with complete instructions for use.

Temperature Control

It is now recognised that the structure and properties of metals is dependent to a great extent on temperature and their successful heat-treatment depends upon control of the temperature of the product in heating and cooling. The growing need for fine limits in the use of heat to obtain the most satisfactory results has led to great improvements in the design of temperature controllers, as a means of maintaining the temperature conditions which research and experience have shown to be most suitable for a particular product. So great is the progress in the design and construction of these instruments for industrial use that it seemed doubtful whether further progress was possible, but improvements have recently been incorporated in the Kent Multelec which are noteworthy.

The instrument is designed to control any temperature up to 3,000° F., and, as a result of much accumulated experience, the new design, known as Mark II Multelec, embodies all the fine points of its predecessor, the Mark I, as well as many new features. For example, the length of visible chart has been increased to 10 in., representing 10 hours' operation on the standard 1-in.-per-hour chart, but alternative chart speeds of 2 in. and 3 in. are also standard on all machines, the change being effected by gear lever.

As will be noted in Fig. 1, no mechanism is visible from the front, and the indicator for the scale is specially arranged to be visible at long distance, while the control setting scale is also more prominent, and internal illumination is improved. The front measuring mechanism is very easily accessible by means of the new drop chart frame, shown in Fig. 2, which also makes chart changing very simple and at the same time provides access to the galvanometer and relay mechanism. The multi-point recorders have a target indicator, which shows which point the recorder is measuring, visible at some distance. Another improvement is that the chart can be cut off and will continue to drive, while a plate provided at the front of the instrument allows notes to be made on the chart.

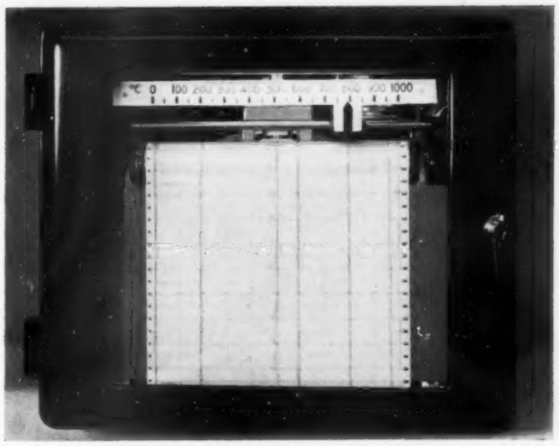


Fig. 1.—The new Multelec; it will be noted no mechanism is visible from the front.

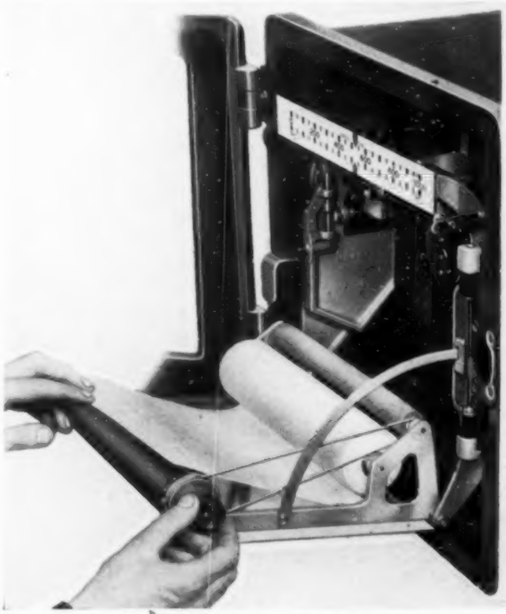


Fig. 2.—Showing the new drop chart frame.

The object of temperature control is to control the rate of heating—in some cases to control the rate of cooling—to prevent overheating of surfaces of the charge, and to maintain the heating effect, and automatic operation of the temperature control equipment is essential to accomplish this end. The accuracy of the control is determined by the thermo-couple and the temperature instrument and the Mark II Multelec manufactured by George Kent, Ltd., incorporating all the outstanding features associated with its predecessor Mark I, but including the additional improvements mentioned, greatly simplifies the maintenance of temperature control to a high degree of accuracy.

Twist Drill and Reamer Fluting Machine

An interesting machine designed to mill the flutes in three drills or reamers simultaneously, either parallel or spiral, has recently been constructed by Messrs. Herbert Hunt and Sons, Ltd., Elsinore Road, Old Trafford, Manchester, 16.

The drill blanks are held in three self-centring chucks at the shank ends and are supported in bushes through which they are traversed while being milled. The milling cutters are mounted immediately above the blanks to be fluted. The chuck spindles have adjustment, so that when spirals are being milled and the carriage is set at an angle to the cutter spindle, the cutters commence cutting simultaneously on all the blanks. The feed motion to the carriage is automatic, and variation is obtained by slip gears. At the end of the cut an automatic trip motion operates, and the carriage is lowered clear of the cutters. The carriage is returned to its starting position by hand-wheel.

Dividing from one flute to another is effected by a hand lever which operates a pawl engaging with the dividing plate, a spring-loaded locking plate being provided. A leader bar and nut provide for the various pitches of the spirals. The three work spindles are equipped with Timken tapered roller bearings mounted in pairs. On the traverse screw and elevating screw tapered roller thrust bearings are used, while the cutter spindle also is mounted in tapered roller bearings and is driven by spiral bearing which runs in an oil bath. Machines are supplied with a motor drive or, alternatively, they can be driven by fast and loose pulleys.

Stability of Alloys for Springs

The Maintenance of Constant Deflection

THE ability of spring material to maintain a constant deflection under a steady load depends on the stability of the material. Lack of stability results in drift or hysteresis which is a slow increase in deflection that continues indefinitely at a constant decreasing rate. Drift or hysteresis is known to increase with an increase in working stress. At low stresses nearly all of this drift is recovered when the load is removed, while at high stresses some of the drift is permanent, and this permanent phase merges with plastic flow or permanent set at stresses above the elastic limit. Drift is also known to be increased by internal stresses or conditions associated with cold working which increase the strength of non-ferrous alloys. Heat-treatment that tends to relieve internal stresses reduces drift, and the temperature of the material when it is under load also affects drift, elevated temperatures causing more rapid changes.

To compare the stability of certain non-ferrous alloys, a series of unusually accurate drift measurements have been carried out recently by L. L. Stott and R. W. Carson.* Beryllium copper containing 2·25% of beryllium, which had been previously shown to be exceptionally free from drift or creep after heat-treatment at a relatively high temperature, was compared with phosphor bronze containing 8% of tin, and a nickel silver containing 18% of nickel and 27% of zinc. Strips of each alloy 4 in. long, 0·5 in. wide, 0·02 in. thick, were subjected to steady bending stresses by loading them as cantilever beams, and drift or increase in deflection under a steady gravity load was measured and recorded automatically on an electronic micrometer. This device consisted of a hand type micrometer with a needle point making contact with a polished steel strip attached to the specimen which with electronic means of determining instant of contact and a relay for controlling a motor for setting the micrometer exactly at the point of contact, recorded drift on the specimen on a moving paper chart, thus eliminating any personal factor in making measurements. This instrument was sensitive to drift effects as small as one millionth of an inch.

Chart records were obtained on each of the materials at calculated maximum stresses of 13·4, 26·8, and 40·2 tons per sq. in. Most tests were run for an hour or longer and test temperatures were maintained at 20° C. Beryllium copper specimen strips were heat-treated for various periods at 300°, 325° and 345° C., and additional tests were made on strips 0·013 in. thick and $\frac{5}{16}$ in. wide which had previously been prepared and tested for hardness. The strips used were those which hardness tests showed to be heated to maximum hardness. All heat-treatments were carried out in a salt bath. From the recording micrometer readings, the heat-treatment was found which gave minimum drift in beryllium copper and this heat-treatment was used for the strips used in the comparative tests. In all the tests, a complete set of specimens of each material were subjected to the same stress under identical load conditions.

It was found for all the materials that the rate of drift decreased with increasing time under load. All drift measurements in the investigations were expressed in per cent. of load deflection rather than in actual measurements, since materials with different elastic constants deflect different amounts under the same stress. It was shown that, if drift was measured with sufficient accuracy during a short period and the time plotted in logarithmic scale for drift in per cent. of load deflection, all the measurements fell on a straight line. The slope of this line and the amount of drift at any given time determined the stability characteristics of any material, and if the tests were made with sufficient accuracy, a test of 30 minutes duration was sufficient to measure this property. Because of the relatively rapid rate of drift during the first few minutes, readings taken during this time were subject to comparatively large errors, and therefore in each of the measurements made on the various materials the drift was measured for the period from 2·5 to 32·5 minutes after applying the load.

In preliminary tests it was found that a bending stress of 26·8 tons per sq. in gave a sufficient amount of drift to result in accurate determinations in 30 minutes, and this stress was used to find the effect of various heat-treatments on drift in beryllium copper. At 300° C. minimum drift required heat-treatment for at least 2 hours. At 340° C., at the end of 5 minutes, drift was already much lower than the minimum observed at 300° C. Although minimum drift following 340° C. required 30 minutes at this temperature, softening during this time would reduce the strength, therefore, a maximum time of 20 minutes at 340° C. was used for all the tests. In general, the results of the investigations on the effect of heat-treatment on drift showed that a relatively high temperature was required for maximum stability.

Small increases in stress caused large increases in drift. Testing for a period of 30 minutes, accurate measurements were only obtained for stresses of 13·4 tons per sq. in. and higher, but drift at lower stresses was measured readily by extending the duration of the test to 2 or 3 hours. For beryllium copper springs a maximum working stress of 18 to 22 tons per sq. in. was necessary to secure stability. The drift/stress curve obtained for beryllium copper was found to fit all three alloys, when the scale for the ordinate was properly selected, which meant that drift in all of the materials could be expressed by the equation :—

$$\text{Drift} = \text{Constant} \times \text{Stress } 5{\cdot}3$$

The only difference between the equations for the three materials was in the value of the constant. A comparison based on one stress was also found to apply to other stresses in the range from 13·4 to 40·2 tons per sq. in. and a simple ratio was therefore obtained for the alloys tested. Rating drift in beryllium copper as 1·0, the drift in nickel-silver was 1·4, and in phosphor bronze 2·8.

The tests showed that, on flat strip, the best stability was obtained within only a relatively limited range of time and temperature of heat-treatment. Experience also showed that this heat-treatment was affected by the cold reduction in area and the forming or bending operations performed on the strip. A somewhat different heat-treatment was required to obtain minimum drift in beryllium copper springs coiled from wire, and in such springs it was usually necessary to make a drift determination on finished springs in order to arrive at the best heat-treating time and temperature.

* *Metals and Alloys*, 1938, vol. 9, No. 9, pp. 233-236.

Erratum

In the article by Herr Röhrig, published in our last issue, entitled "Trends of Development in the Aluminium Industry of Germany," reference is made to the growth in aluminium consumption that has taken place in Germany in recent years, and a table is given which demonstrates this, and also provides a comparison with the total world consumption. In this table, which is given on page 126, an error inadvertently occurred ; the second item : "The world (including Germany), should read : "The world (excluding Germany)."

For convenience, the table is reproduced in a corrected form :

(The figures represent thousands of tons).

Year :	1929.	1930.	1931.	1932.	1933.	1934.	1935.	1936.	1937.	1938.
Greater Germany (not including Sudeten area)..	39·8	28·6	24·5	19·5	82·6	52·9	87·4	104·7	132·9	175
The world (excluding Germany)...............	231	181	152	120·2	127·4	174·5	217·9	294·6	368·8	375

The United States Aluminium Industry in 1938

Production only slightly less than 1937 record

NEW aluminium production in the United States during 1938 was only slightly less than the record output of 1937, according to the Bureau of Mines, United States Department of the Interior. A total of 286,882,000 lb., valued at $56,659,000 was produced in 1938, compared with 292,681,000 lb., valued at $55,609,000 in 1937, a decrease of only 2%. For the first time in recent years the plant at Alcoa, Tennessee, produced more metal than the plant at Massena, New York. The Alcoa works accounted for 40%, and the Massena works for 34% of the aluminium made in the United States in 1938. The balance was produced at Badin, North Carolina, and Niagara Falls, New York State.

Though aluminium production declined only slightly in 1938, domestic consumption declined very sharply, and stocks of primary aluminium were increased by 112,959,000 lb. In previous years the large stocks accumulated prior to 1934 had been reduced steadily. Aluminium imports for consumption also declined in 1938. Since domestic exports of aluminium increased and metal production in most other countries increased, it appears that aluminium consumption outside the United States increased appreciably in 1938.

A large part of the expansion programme started by the Aluminium Company of America in 1937 was completed in 1938. Of outstanding interest was the new alumina plant at Mobile, Alabama, which commenced operations on July 26, 1938. The alumina is manufactured from South American bauxite by means of the Bayer process. The new sand foundry and forging plant at Los Angeles, California, was completed in 1938 to better serve increasing demands for aluminium alloys by the aircraft industry in that area. Other developments during 1938 included a new extrusion mill at Lafayette, Indiana, expansion of the rolling mill at Edgewater, New Jersey, and the installation of arc rectifiers in reduction plants at Alcoa, Tennessee, and at Massena, New York.

Although the domestic consumption of aluminium in 1938 was low due to the recession in industrial activity, the marked upturn in business during the closing months of the year was significant. The aircraft industry, one of the large users of aluminium, enjoyed a high rate of activity during 1938, and faces the greatest year in its history in 1939. Aluminium alloys, because of their strength, durability and lightness, continued to play a large part in the construction of airplane engines and bodies. In addition to increased manufacture of all sizes and types of commercial and military planes, the building of superplanes, such as the larger clipper ships, expanded.

Other fields of transportation that use a large quantity of aluminium are the street car, railroad, ship, and automobile industries. During 1938, new aluminium street cars were put into service on Broadway in New York City. The design of one of Union Pacific's streamlined trains was modified by using aluminium shapes and plate. It is expected that the 1939 railroad rehabilitation programme will call for more streamlined construction with lightweight material. In 1938 a weight reduction of more than 3,000 lb. was obtained in each of 40 locomotive cabs built for the New York Central Railroad by using aluminium alloy. The nose pieces of a number of the railroad's streamlined engines ere cast of aluminium. It has been found that the application of aluminium forgings to locomotive crosshead slippers greatly reduces rail pounding. Some of the experimental locomotive main and side rods made of aluminium have given excellent performance for more than 160,000 miles of operation. A possible future field for aluminium in transportation is in ship hull construction. An experimental test hull, exposed to salt water for three years, was recently found to be in excellent condition. The aluminium life-boats installed in the United Fruit Company's *Veragua* two years ago have proved very serviceable, and additional units are being considered. For the automobile industry aluminium fabricators continue to manufacture pistons, cylinder heads, and many other parts. Die-cast aluminium-cylinder blocks are being made for aluminised outboard motors. Other recent applications of aluminium in the transportation field are in the construction of tank-cars for dangerous and inflammable materials, Diesel engines, ice-boats, and in mine transport cages.

Since 1897 aluminium cable has been used for high-voltage transmission lines, and for more than 25 years it has been employed for rural electrification, and more than 700,000 miles of aluminium cable, steel reinforced, have been manufactured in the United States.

Some Aspects of the Recrystallisation of Cold-Worked Aluminium and Aluminium Alloys

Those concerned with the annealing and heat-treatment of aluminium and aluminium alloys appreciate that after cold-working a coarser grain is usually produced by slow heating than by more rapid heating. Consequently, for the control of grain size produced by annealing or heat-treating cold-worked aluminium and aluminium alloys, the heating rate is of considerable practical importance. Some preliminary work on the recrystallisation of aluminium and aluminium alloys led to a study by L. W. Eastwood, R. W. James and R. F. Bell* of the relationship of the type of microstructure of an alloy to the effect of the heating rate.

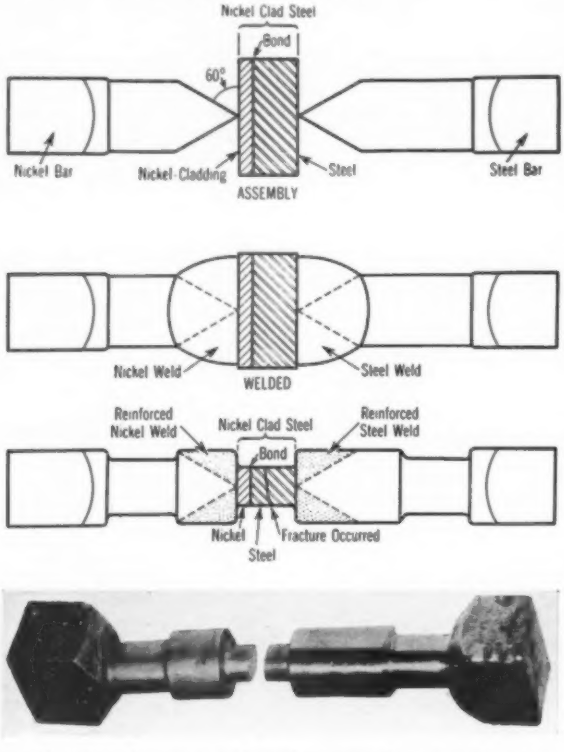
The investigation embraced three different classes of aluminium-base alloys. The first comprising a single phase at all temperatures between the solidus and room temperature, the second a single phase at temperatures near the solidus and two phases at room temperature, while the third class of alloys comprised two phases at all temperatures below the solidus line. It was found that the grain size after annealing or heat-treating the cold-worked materials of the first class was unaffected by heating rate. The second class of material, containing a second phase completely soluble at high temperatures, was unaffected by heating rate within the limits of the experiments described provided the soluble materials are completely dissolved during the heating operation, thus leaving a single-phase material. It is shown that the temperature is such that the soluble materials remain in part undissolved, this class of alloys is affected by heating rate much as in class III. It has been found also that alloys of class III—i.e., materials that contain a second essentially insoluble phase dispersed in the aluminium-rich matrix—produce a coarser grain when the cold-worked material is slowly heated than when rapidly heated.

An investigation of the grain size of high-purity aluminium shows that if recrystallization of the cold-worked material is just complete—that is, if no coalescence has occurred—the grain size is independent of the time and the temperature of the anneal, and for a given material, is dependent only upon the degree of deformation. In this respect, high-purity aluminium is similar to alpha brass.

* *Metals Technology*, American Institute of Mining and Metallurgical Engineers. T.P. No. 1048, February 1939.

A Test for Nickel-Clad Steel

WHEN a big piece of equipment is required for handling corrosive products nickel-clad steel is now being increasingly specified. The nickel side of this material is in contact with the corrosive, and the additional strength resulting from the thicker steel backing is more than adequate to enable large structures to be erected. Thus, strength and corrosion resistance is obtained at relatively little expense.



Showing the preparation of test specimens and one of the specimens tested.

Usually the thickness of the nickel sheet is about one-tenth of the total thickness of the two metals, nickel-clad steel being produced in plates $\frac{3}{16}$-in. thick and heavier. The two metals are inseparably bonded, and a brief description of a recent test which was carried out to determine the strength of this bond may be of interest.

A bar of nickel and one of steel were machined with a 45° cone at one end. Between these, a nickel-clad steel specimen was held in position and welded. Nickel welding rod was used to join the nickel bar to the nickel cladding, and, of course, steel welding rod provided the joint between the steel bar and the steel side of the clad metal.

A machined tensile specimen with a reduced section of 0·505-in. diameter was produced. The finished specimen was placed in a tensile testing machine. The steel weld fractured at 22·6 tons per sq. in., but the rest of the specimen and the nickel-to-steel bond remained intact. The result indicates that there is no possibility at all of the nickel cladding becoming separated from the steel during service.

Pure Zinc—The Influence of Minor Constituents

A method of preparing spectrographically pure zinc is described in detail by Messrs. E. C. Truesdale and Gerald Edmunds in the February, 1939, issue of *Metals Technology*. Examples are given showing the influence of minor constituents, both natural and added, on the compression failure of zinc, and of a trace of copper on the microstructure of zinc. Attention is also directed to the influence of magnesium upon the corrosion resistance and creep strength of certain zinc alloys.

International Foundry Congress, 1939

PLANNED by the Institute of British Foundrymen, under the auspices of the International Committee of Foundry Technical Associations, the next International Foundry Congress will be held in London from June 12 to 17, and will be followed by a tour of the principal foundry centres of Great Britain from June 18 to 24 and from June 25 to 30. The President of the Congress will be Mr. W. B. Lake, J.P., President of the Institute of British Foundrymen for 1939-40. A number of prominent industrialists and scientists have consented to give their patronage to the Congress, the Secretary of which will be Mr. T. Makemson, Secretary of the Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, 3.

It is expected that about five hundred delegates will attend the Congress from the majority of European countries, the United States of America, and from many parts of the British Empire. The programme for the Congress caters for the presentation of more than twenty papers to be presented by authors representing the Institute of British Foundrymen, and the equivalent foundry technical associations in other countries. A feature of great interest will be the presentation of the annual Edward Williams lecture by Professor W. L. Bragg, O.B.E., M.A., D.Sc., F.R.S. The managements of a number of works have consented to their plants being opened for inspection by the delegates, who will also be able to visit the National Physical Laboratory. A delightful programme of evening functions has been arranged, whilst ladies will be able to see places and industrial establishments of interest to them.

A Post Congress Tour has been arranged which is divided into two sections, so that delegates, whose time in England is limited, may return on June 24 if they wish. The tour is largely occupied by works' visits, but opportunities are also given to see the scenic beauty of Great Britain, and in the evenings delegates will often be the guests of the various branches of the Institute of British Foundrymen. All those who are interested in the Congress and/or the Post Congress Tour, are asked to communicate either with the nearest office of Messrs. Thos. Cook and Son, Ltd. (Cook/Wagon-Lits-World Travel Service), who have been appointed official travel agents for the Congress, the Secretary of the foundry technical association of which they are members, or the Secretary of the Institute of British Foundrymen, at the address given above.

Bessemer Gold Medal Award

The Council of the Iron and Steel Institute has this year awarded the Bessemer Gold Medal to Mr. James Henderson. This award was founded by Sir Henry Bessemer, and is awarded annually for distinguished merit in promoting the technical and metallurgical development of the iron and steel industry; it is the highest honour which the Institute can give.

Mr. James Henderson has had a remarkable career. For 45 years he was associated with the technical development of the Frodingham Iron and Steel Company Ltd., in North Lincolnshire, and held all positions from chief metallurgist to managing director. During that period the works became one of the most important in the country and were associated with such important developments as the introduction of the Talbot direct metal process, the use of blast-furnace gas in blowing and power engines, and the installation of modern plate mills.

Mr. Henderson is now deputy-chairman of the renamed Appleby-Frodingham Steel Company Ltd., and a director of the United Steel Companies Ltd.; he is past-president of the British Iron and Steel Federation and of the Lincolnshire Iron and Steel Institute; a former chairman of the Lincolnshire Ironmasters' Association and of the Iron and Steel Industrial Research Council; a member of council and honorary treasurer of the Iron and Steel Institute.

Business Notes and News

National Savings Holiday Schemes

Wide attention has lately been drawn to the schemes put forward by the National Savings Committee for the encouragement of saving for holiday purposes. The schemes have been adopted by a large number of firms in many trades. One of the main reasons for the success of the schemes is the fact that they have been given commendation by many important Trade Federations. The following are amongst the organisations which have supported the schemes in this way: Coal Mining and Mining Association; Engineering and Allied Employers' National Federation; Glass Manufacturers' Federation; Surgical Instrument Manufacturers' Federation; Dock and Harbour Authorities; National Federation of Vehicle Trades; Iron and Steel Trades Employers' Association. Similar action has been taken by certain leading trades unions.

European Climax Molbydenum Company

It is significant that Climax Molybdenum Company, of New York City, U.S.A., has formed a new company, under the title of Climax Molybdenum Co. of Europe Ltd., with headquarters at 2-3, Crosby Square, London, E.C. 3. The object of this company is not concerned with the sale of molybdenum, but to act primarily as a technical service bureau and to supply information likely to assist in the use of molybdenum.

Considerable progress has been made in the use of molybdenum in recent years, and it is noteworthy that during 1938, when the United States experienced a depression, which reduced the output of all industrial minerals, molybdenum constituted an exception. The Climax Molybdenum Co., which produces over 70% of the world's needs, increased its production to 251,340 cwts., compared with 203,125 cwts. in 1937. European countries rely mainly on the United States for supplies of this metal, which has such a marked effect in improving the properties of heat-treated steels, either alone or in conjunction with other alloying elements, and this Service Bureau should prove of great assistance to users and potential users of this valuable metal. Some indication of the growing use of molybdenum will be gathered from the fact that in 1937 82,328 cwts. were imported by Great Britain, of which 78,041 cwts. were supplied by the United States; in comparison, the total for 1933 was 12,184 cwts.

One of the directors of the new company is Mr. R. F. Rowden, formerly with High Speed Steel Alloys, Ltd., and later with The Mond Nickel Co., Ltd., and all interested in the use of molybdenum are asked to communicate with the company at the London address.

Royal Aeronautical Society Awards

The following awards have been made by the Council of the Royal Aeronautical Society: The Silver Medal to Major R. H. Mayo, O.B.E., M.A., for his work leading to an advancement in design; the Taylor Medal to Squadron-Leader H. P. Fraser, A.F.C., B.A., for his paper on "High Wing Loading and Some of Its Problems from the Pilot's Point of View"; the Wakefield Gold Medal to Mr. Leslie L. Irwin, for his work on parachute design, which has led to safety in flying; the Busk Memorial Prize to Squadron-Leader G. M. Buxton, R.A.F., for his paper on "The Development of Sailplanes," and to Mr. H. F. Vessey, for his paper on "Effect of Wing Loading on the Design of Modern Aircraft, with Particular Regard to Take-off Problems"; the Pilcher Memorial Prize to Mr. H. E. H. Rochefort, Wh.Sch., for his paper on "The Theory and Practice of Stressed Skin Construction for Aeroplanes"; and the Usborne Memorial Prize to Mr. P. F. Raynor, B.Sc., for his paper on "Notes on Aero Engine Research."

It should be noted that after March 25 the Society will be in its new headquarters at 4, Hamilton Place, W. 1.

British Built Ships for Cuba

London bankers have, we understand, completed negotiations with Cuba for the building of several vessels for the Cuban mercantile marine. Financial negotiations have been in progress for many months following the Anglo-Cuban trade agreement. Last August it was stated that a new Cuban shipping company had been formed and was making arrangements to place large orders with British yards. Later, however, negotiations were held up, as the British authorities insisted that if the finance necessary for the building of the ships was to be raised in England there should be no discrimination against British vessels using Cuban harbours. This concession has now been granted. It is stated that the orders for new vessels is valued at about £3,000,000, and a number will be built in yards on the North-East Coast.

Welsh Tinplate

The demand for tinplate is showing a welcome revival, and as a result the South Wales mills are operating at more than half capacity for the first time in a year. The distribution of a recent £5,000,000 order, from the American Canning Co., has not yet been decided, but it is expected that the Ebbw Vale Works will receive the largest allotment.

Shipbuilding Costs

There can be no doubt that in many instances Continental shipbuilders have been able to underquote British shipbuilders, but the statement made by Mr. Robertson F. Gibb, in his recent presidential address to the Chamber of Shipping, has raised much controversy. He stated that British shipbuilding prices were 17% above the lowest Continental quotations. While this may have been true in a particular case for a vessel of a special type, it is not considered to be by any means general. There is truth, however, in the statement that, since the armament programme began, prices have increased. Naval yards have undoubtedly benefited from the defence programme, but the programme has been instrumental in leading to an increase in costs that has seriously affected the mercantile builders.

It is necessary to face facts, and whether by reason of subsidies, an easily manipulated exchange, or by reason of the effect of the defence programme on British costs, Continental builders have been able to underquote British shipbuilders, and it is necessary to adopt some means to enable British yards to obtain their fair share of new construction. Shipbuilding is too important an industry to this country to allow its activities to lapse, due to lack of interest in any scheme designed to give British shipbuilders reasonable hope of success.

I.A.E. Research

A problem which has become increasingly prominent in recent years is the excessive gas leakage or blow-by past the piston rings, which occurs on some engines at high speeds. High blow-by is, of course, objectionable because of fumes, and it may also have an adverse effect on the lubricating oil film on the cylinder walls, resulting in piston-ring scuffing. In certain severe cases excessive blow-by is associated with breakage of piston rings, almost invariably adjacent to the ring gap. The occurrence of blow-by and ring breakage are undeniably facts of observation, but the cause is still a matter of theory; it is usually attributed to "ring flutter"—i.e., to a vibration of the piston rings.

Experiments on this problem have been carried out at the I.A.E. Research Department during the past two years on three engines, viz., an overhead-valve, water-cooled, single-cylinder petrol engine, an air-cooled motor-cycle engine at speeds up to 7,000 r.p.m., and on a four-cylinder automobile engine at speeds up to 5,500 r.p.m. The experimental arrangement involves special methods of sealing the crankcase, the blow-by gases being collected and measured in a gasometer. Particular attention has been given to the effect of radial pressure, thickness and clearance of the piston rings, while the influence of many other factors, such as engine load, ignition advance, cylinder bore distortion, oil viscosity, quantity of oil, etc., has been studied. In addition, chemical analysis has been made of the blow-by gases, which has helped to throw light on the problem. As a result of these experiments it has been possible to evolve a tentative theory to explain the origin of "ring flutter." A report, describing in detail the results of this investigation, is being released shortly

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ALUMINIUM.

98/99% Purity		£94	0	0

ANTIMONY.

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Chinese		49	0	0
Crude		36	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11½
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9⅜
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	4⅞

COPPER.

Standard Cash		£43	12	0
Electrolytic		49	0	0
Best Selected		47	15	0
Tough		48	10	0
Sheets		78	0	0
Wire Bars		49	0	0
Ingot Bars		49	0	0
Solid Drawn Tubes	lb.	0	1	0¾
Brazed Tubes	,,	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum ° ,,		0	4	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	34	15	0
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	24	5	0
NOMINAL 6-8 Carbon, scale 7/6 per unit	,,	23	15	0
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Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97-98% Mn	lb.	0	1	3
†Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25-50%	,,	0	14	0
§Spiegel, 18-20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	10	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	7	6
S. Wales	—	1	7	6
Durham	—	1	4	2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£66	0	0
*Commercial Ingots		49	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£12	5	0
N.E. Coast—			
Rivets	—		
Best Bars	12	15	0
Crown Bars	12	5	0
Lancashire—			
Crown Bars	12	5	0
Hoops	13	12	6
Midlands—			
Crown Bars	12	5	0
Marked Bars	15	5	0
Unmarked Bars	—		
Nut and Bolt Bars	11	0	0
Gas Strip	13	12	6
S. Yorks.—			
Best Bars	12	5	0
Hoops	13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11¼
†Sheet to 10 W.G.	,,	0	1	0
†Wire	,,	0	1	1⅜
†Rods	,,	0	1	1½
†Tubes	,,	0	1	6¾
†Castings	,,	0	1	3

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Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	0	0
Foundry No. 1	5	2	0
,, No. 3	4	19	0
,, No. 4	4	18	0
Silicon Iron	—		
Forge	4	18	0
Midlands—			
N. Staffs. Forge No. 4	4	18	0
,, Foundry No. 3	5	1	0
Northants—			
Foundry No. 1	5	1	6
Forge No. 4	4	17	6
Foundry No. 3	4	18	6
Derbyshire Forge	4	18	0
,, Foundry No. 1	5	4	0
,, Foundry No. 3	5	1	0
West Coast Hæmatite	6	12	0
East ,, ,,	6	11	0

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Brass	21	10	0
Gun Metal	35	0	0
Zinc	8	10	0
Aluminium Cuttings	59	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	2	0
Scotland	2	19	0
Cleveland	3	0	0
Cast Iron—			
Midlands	2	15	0
S. Wales	3	2	0
Cleveland	3	12	6
Steel Turnings—			
Cleveland	—		
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	—		
Scotland	1	14	0

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G.O.B. Official	—		
Hard	£9	15	0
English	15	2	6
India	13	15	0
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North-East Coast	10	10	6
Midlands	10	10	6
Boiler Plates (Land) Scotland	11	8	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	11	8	0
,, ,, (Marine) ,,	—		
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,, North-East Coast	10	8	0
,, Midlands	10	8	0
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Fishplates	13	10	0
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Hard Basic .. £8 10 0 to	10	0	0
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METALLURGIA.

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For MARCH, 1939.

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Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited Hotspur Press, Manchester and London.


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